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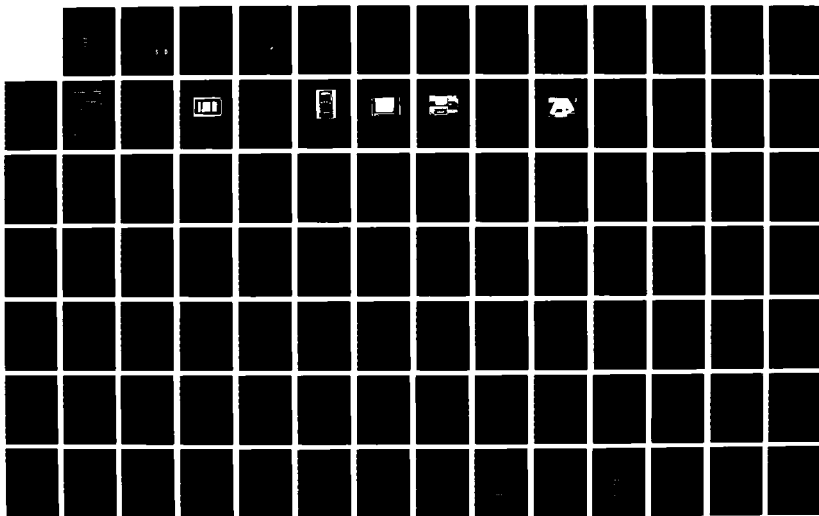
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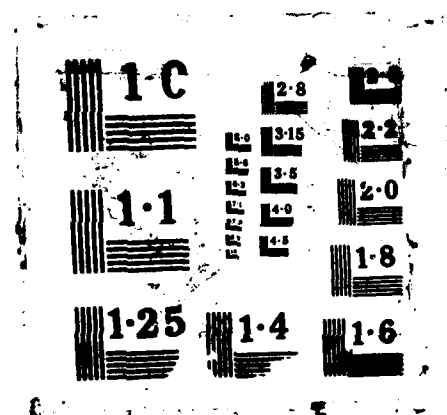
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AN EXPERIMENTAL STUDY OF A SIX  
KEY HANDPRINT CHORD KEYBOARD

Sheldon A. Wolstein<sup>1</sup>

May 1986

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## 20. ABSTRACT (Continued)

keypad with and without memory aids. Use of Mnemonic memory aids increased the number of errors made on the chord keyboard. The 4x4 keypad was found to have significantly less errors than the chord keyboard.



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**AN EXPERIMENTAL STUDY OF A  
SIX KEY HANDPRINT CHORD KEYBOARD**

**Sheldon A. Wolstein**

**Interim Report  
on Project  
"Human Factors Studies of Data Entry Devices  
and Techniques"  
Report No. RF 7053-21  
Contract DAAA15-86-K-0010**

**May 1986**

**Texas Transportation Institute  
Human Factors Division  
The Texas A&M University System  
College Station, Texas 77843-3135**

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The views, opinions, and/or findings contained in this report are those of the authors, and should not be construed as an official Department of the Army position, policy, or decision unless so designated by other documentation.

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## INTRODUCTION

Chord keyboards are data entry keyboards which use the simultaneous activation of two or more keys to input alphanumeric characters. Although not new, these types of devices have been the subject of both popular and industrial interests as data entry devices for the non-typist. The original interest in chording keyboards dates back to the late fifties and early sixties. These early devices had keys ranging in number from 4 to 12. Operation was ordinarily two handed. Of these early mechanisms, the court reporter's steno-writing system is best known.

The set of possible chords with only 7 keys (the summation of combination of 7 keys taken 'n' at a time ( $n=1,2,3,4,5$ ) is equal to 127) is larger than the set of keys available on standard keyboards. The extra chords are then used for special characters, operator assignable functions, syllables or even entire words or phrases. The Velotype is just such a device (Special Systems Industry, no date). With 37 keys on the board, both hands are used. The keys are arranged in three groups. The left side has the initial consonants, the right side is almost a mirror image of the left and is dedicated to final consonants, vowels are in the middle (see Figure 1). The lesser used letters do not have dedicated keys but are instead generated by a two-key chord (e.g. T+J=D). With this layout, a three letter syllable can be spelled out with a three-key chord.

Some studies were cited in the sales literature for the Velotype, such as an undocumented study by the Dutch Association for Stenography and Office Practices. No quantitative results were reported but the conclusions they felt justified in making were:

1. The typing speed inexperienced velotypists can reach is three times as high as the speed of an experienced typist.
2. The speed of an experienced velotypist is approximately 900 to 1000 strokes per minute. This is faster than normal speech (bold face theirs) The speed of an experienced typist is between 250 and 300 strokes per minute.
3. Learning to velotype takes only 25% of the time it takes for traditional typing in order to reach the same average typing speed.

No other performance or learning studies are listed.

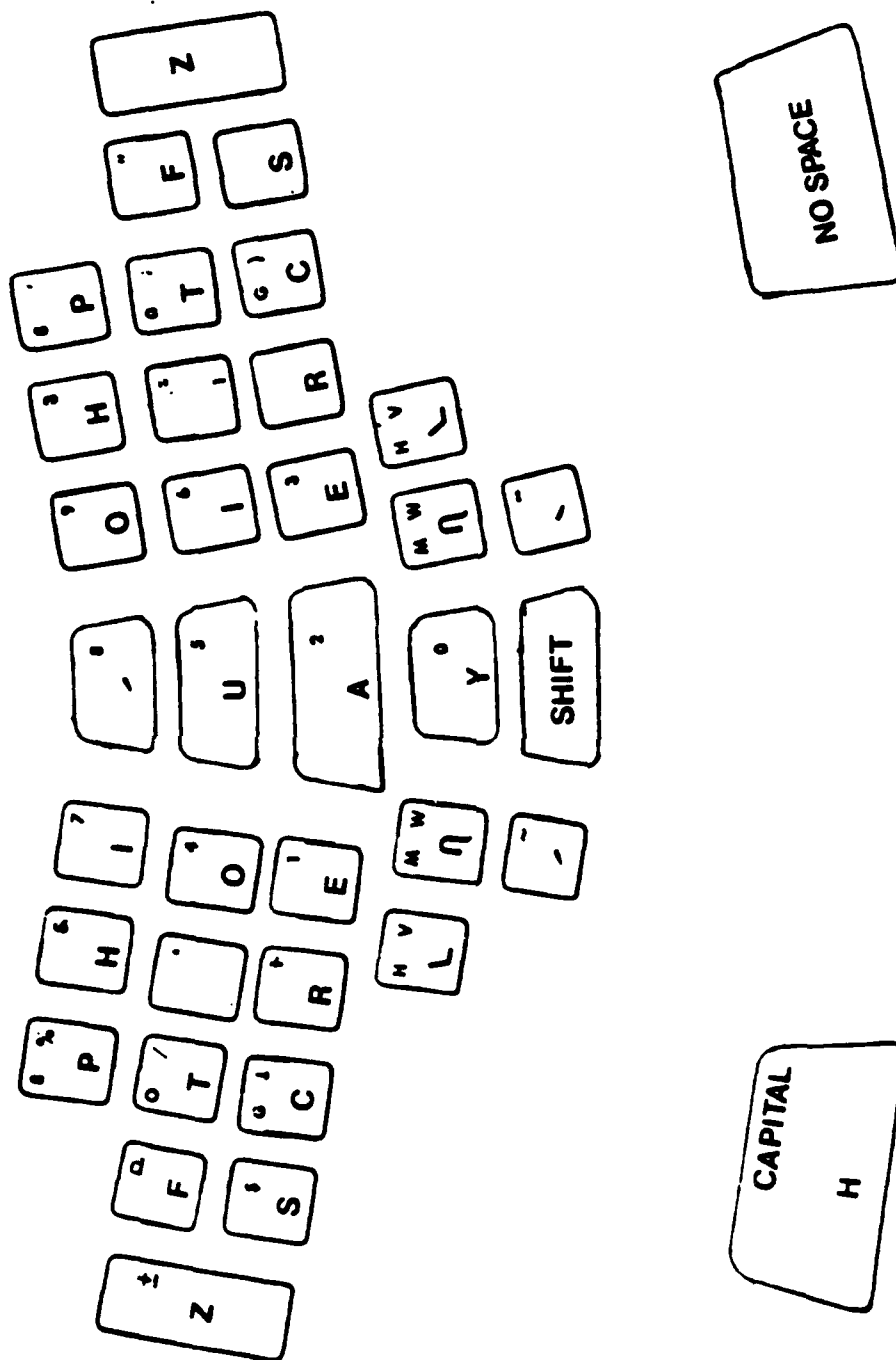


FIGURE 1

Velotype keyboard

During the 1970's Nathaniel Rochester and Frank Bequaert developed another device with several keys per finger (Rochester, et al 1977). Their device had a five by two array of keys with a row of four rectangular thumb keys (see Figure 2). With the letters plotted on the corners, the keys utilized a swivel type activation. The designers claim 4407 possible chords, using only the thumb and the three strongest fingers of one hand.

Generally, there is a smaller number of keys present on a chord keyboard than on a standard keyboard. Each key is used several times in different combinations to produce various characters. This aspect of chording allows fewer keys to produce the same character set and this in turn, allows the board to be smaller than conventional keyboards. The smaller size enables these keyboards to be placed where other keyboards cannot be used. Also with fewer keys, many can be operated with one hand. These two features eliminate the need for the board to be immediately in front of the operator. This gives rise to unique applications such as operation within a cockpit of aircraft, conceivably under acceleration conditions. There is improvement of less novel workstations since the uncomfortable and stressful position common to typing is eliminated, thereby improving the ergonomic acceptability of the keying task.

A "handprint" keyboard is at the opposite extreme from full keyboards because it has the same number of keys as the number of fingers used to operate it, with perhaps one or two extra keys which are used infrequently. With so few keys, there is no motion of the fingers other than for key press; the keys are arranged to allow the fingers to rest naturally above them.

In their report, Alden and his associates state there is supporting data for "the hypothesis that keyboards which tend to minimize the number or the distance of finger-reaching movements are capable of the fastest operation, particularly for special purpose tasks" (Alden, Daniels, and Kanarick, 1972). Klemmer ((1958) as reported in Seibel (1972)) trained two subjects on a two-handed handprint keyboard where the various characters were represented with two key chords. He reported that entry speeds were not "out of line with performance in learning to type on a conventional machine." This early work is reported by Seibel to be the beginning of the investigation of chord keyboards.

Ratz and Ritchie ((1961) as reported in Alden et al (1972)) performed a study to rank the 31 chords that are possible with one-hand. They ranked them with respect to speed: motor constraints (not decision time) as the limiting factor. In a replication of the Ratz and Ritchie study, Seibel (1972) reports very similar times for the 31 chords, and that continuous improvement in discriminative chord reaction time occurred over 30 days. Following this train of investigation, Seibel reports that "...if the effect of motor difficulty is balanced out, the number of alternative chords involved in a given reaction time task makes little or no difference in the reaction time for numbers 5 through 31. The overall average motor difficulty of a set of responses, however, does influence the reaction times for

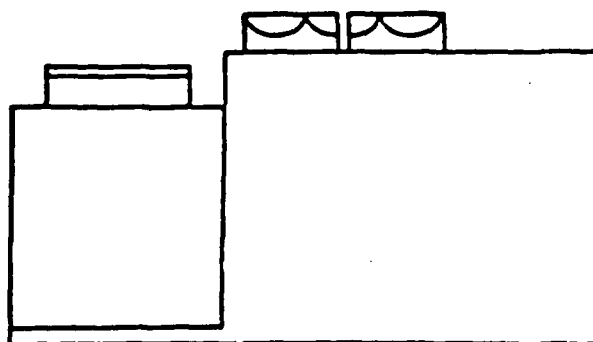
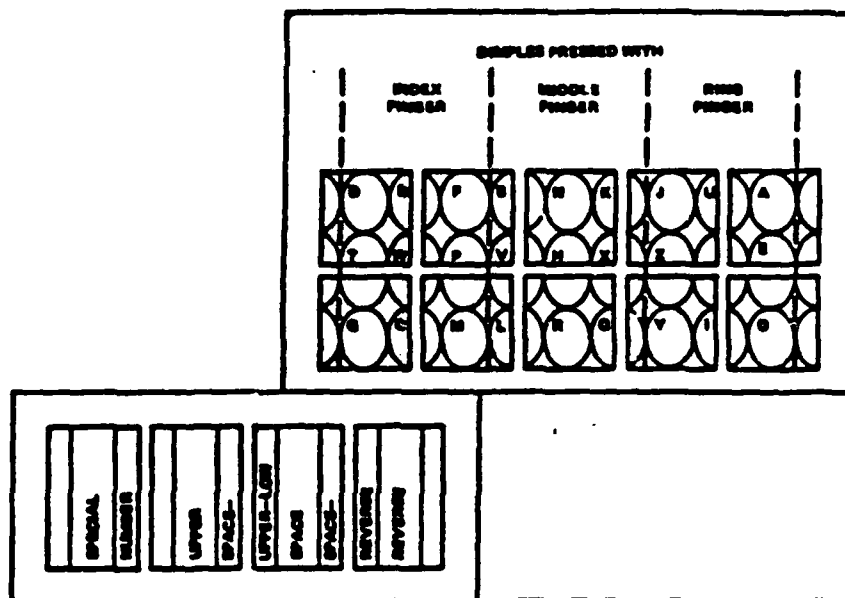


FIGURE 2

Rochester, Bequaert, and Sharp's Chord keyboard

the specific chord responses in the set." (Seibel 1972). This effect is again mentioned in another study by Seibel in which reaction times for 1,023 alternatives are only approximately 25 msec. slower than the reaction times for 31 alternatives. Seibel concludes that "Part of this small difference is attributable to the fact that the larger set contained more difficult chord patterns."

Handprint keyboards designed for one hand operation have certain advantages over keyboards that require two hands. Without the necessity of reaching with both hands, the keyboard may be used in any position, not necessarily on a desk or flat surface in front of the operator. One hand operation and a compact size allow the machine to be used anywhere, on a chair arm, or mounted on the side of the chair near the thigh. It would also be possible to integrate the device in the control column of some types of vehicles, such as high performance aircraft.
































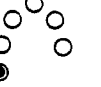
The main argument against most types of nonconventional keyboards is that hunt-and-peck operation is not possible and is therefore not suitable for novice operators. However on a hand print keyboard, with a simple, straightforward method of chording and the proper cue card, this argument may not be valid. Mnemonics are used for example, on the Microwriter, a production chord keyboard by Microwriter Ltd. Some are visual such as the "H" where the crossbar produced by the thumb and little finger is visualized. Others are symbolic, like the "O" which represents the bulls-eye which relates to the center of the hand, the middle finger. The third type of mnemonic is based on wordplay. The "S" is produced by the "S"ignet ring finger (see Figure 3). Rodwell (1980) reports that it took him approximately 30 minutes to learn the alphabet, 30 minutes for numbers and punctuation. Two hours per day for two weeks allowed him to build up to a reasonable speed. While this information is reported in a popular magazine and is anecdotal in nature, it gives an indication that the novice user can use such a device with relatively little experience.

In their study, Lockhead and Klemmer (1959) had operators learning 137 chord patterns in less than 23 hours. These chords however, were not on a handprint keyboard and were also for 100 common words as well as the alphanumeric characters. The learning was without any memory aids. Gopher and Koenig (1983) conducted an experiment using two 5-key handprint keyboards together, one for each hand. Each keyboard was independent from the other and could produce the entire character set. Their objective was to study the best coding scheme to represent identical letters for both hands. The first session was spent in memorizing the codes. No mnemonic is reported, memorization was up to the individual, but all individuals had memorized the codes in 35-40 minutes. Six more sessions at 1.5 hours each were scheduled. By the end of those sessions, no asymptote to speed had yet been encountered.

However, Gopher and Koenig did conclude that:



# ALPHABET - RECOMMENDED LEARNING SEQUENCE

 Straight line up for I	 add a bar at the top for R	 add a bar at the bottom for L	 Reverse L for mirror image J	 Main feature of G is downstroke (opposite to I)
 Horizontal of the M	 Top of the T	 Press completely for P	 First Four Fingers for F FM Radio	 Most Fingers Make M
 Space	 Most common finger (Index) for most common letter E	 The central target - bulls eye	 Signet ring finger	 Very non-U
 The dome of the D Either side of the common line	 The bump of the B	 Looks like a Y	 First upstroke of the A	 Adjoining downstroke of the N
 First downstroke of the V	 The upstroke of the K	 The two sides of the W	 Curl round for C	 Make a tail from the central O
 Everything Xcept your index	 Zig zag between the keys for Z	 Full stop come to a point	 Hyphen	 Comma
 Apostrophe	 Command Key			

Pairs of letters have been  
highlighted by outlining

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FIGURE 3

Microwriter Memory Aids

"In light of the fundamental differences between the two typing keyboards in their skill components, one can conclude that it appears to be easier for humans to commit 52 chords to memory and activate them upon request, than to learn the ways of the hand to a similar number of keys spread out on a typing keyboard."

The study performed by Gopher and Koenig raises questions about the effectiveness of mnemonics for learning chords.

This study addressed the issue of task acquisition and the usefulness of mnemonics in learning the various chords and eliminating errors. Both conditions of chord learning, with or without mnemonics, were compared to the performance on the 4X4 keypad.

For the 4X4 keypad condition, the alphabetic keying method used was that described by Stealey (1985) to be the most efficient of those tested in that study. This is the method of pressing the key with the desired letter and then specify which of the three letters on that key is correct by pressing the key which specifies the letter position; left, center, or right. For example, if the letter "M" was desired, the "6" key was pressed and then the left arrow key (see Figure 4).

#### Study Objectives

The objectives of this study are summarized as follows:

1. Determine which of the keypads, Microwriter or the 4X4 keypad, gives the best performance with limited amounts of training and practice.
2. Determine if the use of mnemonics for chord keypad training leads to a reduction in the number of errors or if the absence of these mnemonics leads to confusion among different chords.
3. Determine the length of time to gain a set level of proficiency of alphanumeric entry on the chord keyboard and on the 4X4 keypad. As an arbitrary level, 50% of the average speed on the beginning QWERTY typing test will be used. Failing to attain that level, the proficiency level on the keypads will be calculated to the nearest 5% of the QWERTY test.
4. Determine if practice on the 4X4 keypad will affect entry rate on the 4X4 keypad.

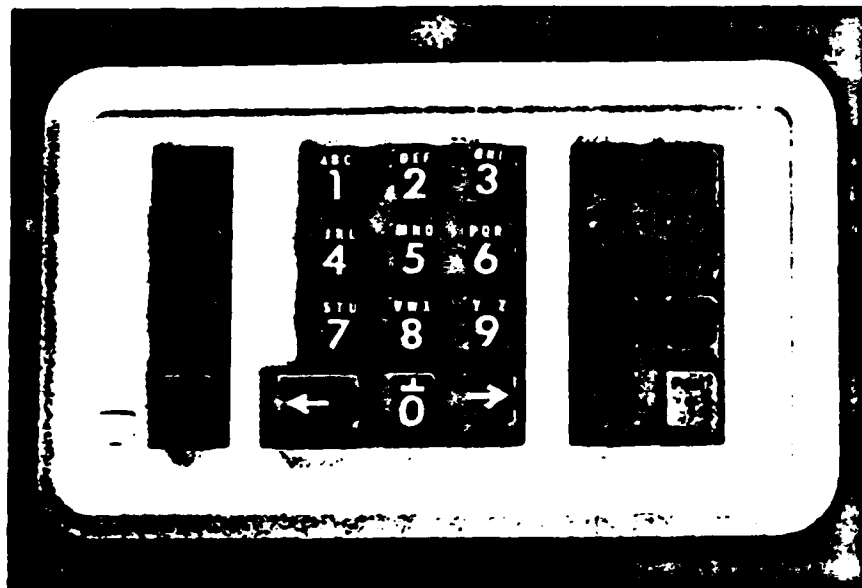


FIGURE 4  
4X4 Keypad

## METHOD

### Research Participants

A total of 15 research participants (10 female, 5 male) participated in this study. The mean age of all research participants was 22.7 years. The range was 20 to 29 years. All of the research participants were students at Texas A&M University; 10 of them were undergraduates, the remainder were graduate students. Average amount of education was 16.5 years with all graduate students seeking a Masters degree. All research participants volunteered their time. Research participants were categorized into one of three typing skill levels (high, medium, and low skill typists), according to their performance on an initial 5 minute typing test taken from a standard typing text (see Appendix A).

### Equipment and Facilities

The study was based on the only commercially available six key handprint keyboard, the Microwriter from Microwriter USA Ltd. It is a book-size device with approximately four pages of memory and a 15 character liquid crystal display (see Figure 5). For a full description and critique refer to Freff (1984). The display on the Microwriter was covered by opaque tape so all research participants would use the Apple monitor described below. The Microwriter, which produces standard ASCII output was interfaced to an Apple IIe microcomputer via a standard communications card.

The Apple accessory numeric keypad was used for the 4X4 keypad. The legends on the keys were covered by a dark covering and new numbers and letters, in white, were inscribed on top. This was necessary so that the keypad which is calculator format, that is "7 8 9" on the top row, could be used in phone format which has "1 2 3" on the top row. Also the letters were labeled on the proper keys as well as the directional arrows (see Figure 4). Software was used to allow the computer to translate the keypad's signals (see Appendix B).

The microcomputer collected speed and error rate information from both the keypad and the Microwriter. Applied Engineering's Timemaster II H.O. clock card was used to gather the time data for all conditions (see Appendix B for all programs used). Apple's standard 304.8 mm (12 inch) monochrome monitor served as the display for all conditions (see Figure 6). Another monitor was used for the experimenter's station (see Figure 7).

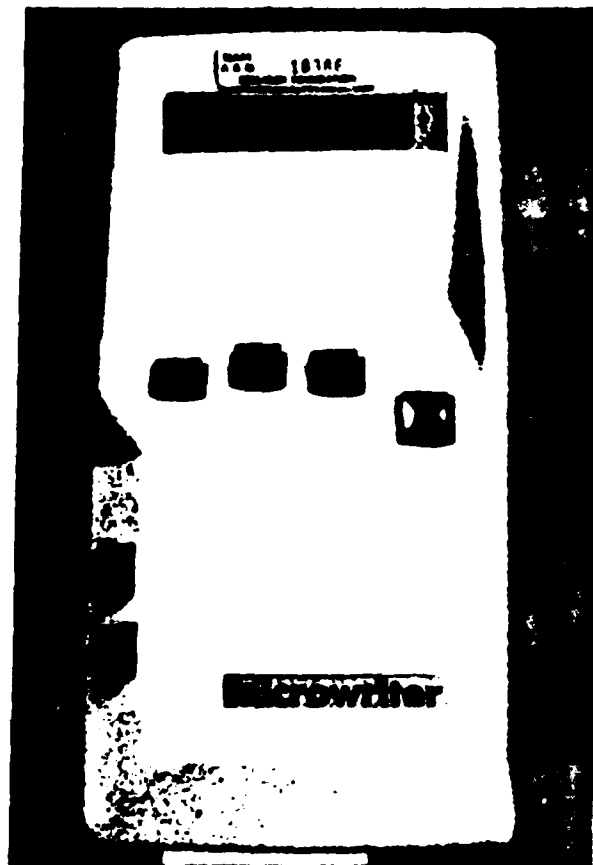


FIGURE 5  
Microwriter Keyboard

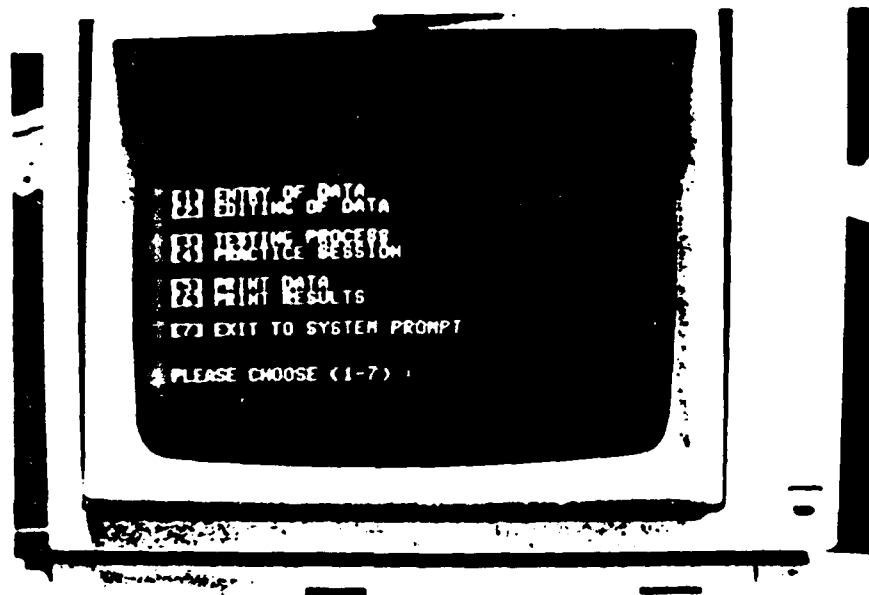


FIGURE 6

Standard Apple IIe Monochrome Monitor with Menu on Screen



FIGURE 7

Experimenter's Workstation

## Procedure

Each research participant was required to read and sign an informed consent form. This document specified the nature of the study and advised the research participant that he or she was free to withdraw from the study at any time for any reason, without bias (see Appendix C).

The initial task performed at the first session was a standardized timed typing test to determine skill on a standard typewriter. This skill level was only used in the assignment to groups, and was not used in the analysis. An IBM Selectric was used. The assignment of research participants to groups was based on the test. A balance of three of medium skill and one each of low and high skill was assigned to each group.

For the chord keyboard groups, training material was similar to the documentation which comes with the Microwriter, but was reprinted and rearranged to eliminate information unnecessary to the experiment and tailored for the two conditions (see Appendices D and E). Also included in the materials for the Microwriter condition were one-sheet cue cards. The cue cards for each condition were equivalent in format, the only difference being that the memory aids were drawn in for the mnemonic condition operators. Appendix F has copies of both cue cards. For the 4X1 group the training material consisted of one sheet explaining the method of keying (see Appendix G).

There was a one hour period scheduled for each research participant each day for a duration of five consecutive days. At the beginning of the first session was the typing test following the completion of the informed consent form, and a demographic sheet. Then after assignment to a group, the research participant was given the training materials appropriate to the condition assigned. The keyboard used by the research participant could be repositioned as needed. All that was in front of the research participant was the keyboard being used, the Apple monitor, and any training material needed (see Figure 8). A 30 minute training and practice session followed. Training was self paced. A proficiency test was then given. All of the Microwriter research participants were able to become acquainted with all letters and numbers within the first session.

The test consisted of two runs of 25 sequences each. The first list was 25 "syllables" of four random letters. The second run was again 25 sequences, but of seven random numbers. These lists were presented on a single sheet of paper (see Figure 9). During the following days the sequences were not changed, but the order in which they were presented changed. This was to compensate for what learning might be possible for essentially meaningless

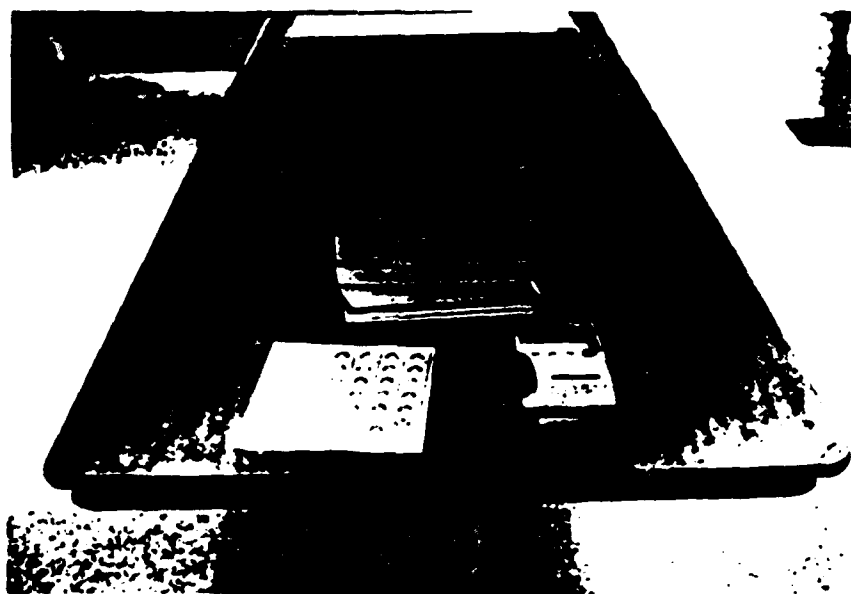


FIGURE 8

Operator's Workstation with Microwriter and Training Material

1. CPLED	1. 0215754
2. FFFN	2. 0554555
3. NQZV	3. 1487160
4. HFXW	4. 3847674
5. ZWYO	5. 9731261
6. RYDJ	6. 1174269
7. SLVD	7. 4336128
8. UZLM	8. 9380620
9. NFWWS	9. 4954013
10. DVIW	10. 3676872
11. EFDN	11. 0709252
12. ZTNS	12. 4310015
13. FGLH	13. 6157006
14. ZAEN	14. 3135283
15. GSUI	15. 5704826
16. LMSE	16. 0924344
17. EDGM	17. 9795535
18. KGDH	18. 9375259
19. CDJD	19. 7262111
20. VSEE	20. 6102074
21. DJG	21. 9783985
22. SEBC	22. 8916097
23. SNCP	23. 2596688
24. NFFR	24. 6144131
25. ZJEH	25. 1132254

FIGURE 9

Sequence Lists as Presented to Operators

material. The characters appeared on the screen as they were entered. No corrections were allowed and the screen cleared as soon as the sequence of four or seven characters was completed. The computer kept track of the sequence time, while total time to complete the list was tracked by stopwatch. Henceforth the term "sequence" will refer to individual groups of four letters or seven numbers. The term "list" will refer to the summary of the 25 sequences.

The computer also kept track of those alphanumeric characters missed on the test. The printout listed the number of incorrect characters entered in the sequence, what was entered, what should have been entered and the time it took to enter it (see Figure 10). This was done to give the research participant an easy comparison between an error and the correct response. The record for the alphabetic list was printed in another room as the research participant was being tested on the numeric list. When the numeric list test was completed, that record was printed out immediately and the entire page with the results of both runs was given to the research participant for review. The experimenter went over the list with the operator and pointed out the mistakes and had the research participant compare finger motions of what was erroneously entered and what was the correct character.

This testing and feedback was repeated every day after the 30 minute practice sessions. The practice sessions were spent typing in news articles which contained both numbers and letters (see Appendix H for example).

### Experimental Design

The model for the study was repeated measures complete block design: condition by days with repeated measures over days. The independent variables in this experiment were condition, which was determined by the keyboard (4X4 keypad, chord keyboard with memory aids, and chord keyboard without memory aids); task (letters and numbers); days (1, 2, 3, 4, and 5); and research participants (1 through 15).

### Dependent Variables

The dependent variables for this experiment were errors-per-list, sequence times, and list times. Sequence time is that interval between the keypress for the first and last letter or number in the sequence. The time was recorded in this way for all 25 sequences in the list. A digital stopwatch used to collect list times was activated manually by the experimenter. The time was started upon hearing the first keypress and stopped upon hearing the disk drive start on the computer which was, for all practical purposes, instantaneous with the final keypress of the last sequence.

CELIA.3LE  
8/28  
END

0 CPLD CPLD 1.751 sec	0 PPKN PPKN 1.577 sec	0 NQZU NQZU 4.399 sec	0 MPXW MPXW 3.608 sec	1 ZMNC ZMNC 4.061 sec
0 RVQJ RVQJ 2.29 sec	0 SLUD SLUD 2.928 sec	0 UZLM UZLM 3.046 sec	0 NKWS NKWS 1.819 sec	0 QOIM QOIM 2.82 sec
0 EFDN EFDN 3.004 sec	0 ZTNS ZTNS 1.618 sec	0 FGH FGH 3.359 sec	0 ZAEN ZAEN 2.256 sec	0 GSUJ GSUJ 1.955 sec
0 LMSE LMSE 3.459 sec	0 EQGM EQGM 2.989 sec	0 KGLW KGLW 2.013 sec	0 CDJO CDJO 2.913 sec	0 USSE USSE 2.008 sec
0 DJOK DJOK 2.493 sec	0 SEBC SEBC 2.374 sec	0 SNCF SNCF 1.844 sec	0 NKFR NKFR 2.921 sec	0 ZJSH ZJSH 4.240 sec

CELIA.3NE  
8/28  
END

0 0215754 0215754 4.614 sec	0 0554555 0554555 2.69 sec	0 1487160 1487160 3.556 sec	0 3897674 3897674 3.263 sec	0 9701201 9701201 3.179 sec
0 1174269 1174269 3.701 sec	0 4336126 4336126 3.5 sec	1 9380626 9380620 3.701 sec	0 4954010 4954010 3.751 sec	0 3676871 3676871 4.057 sec
0 0709252 0709252 3.489 sec	0 4310015 4310015 2.912 sec	0 6157006 6157006 2.93 sec	0 3135283 3135283 3.225 sec	0 5704690 5704690 3.585 sec
0 0924344 0924344 3.506 sec	0 9795535 9795535 3.469 sec	0 9375259 9375259 3.781 sec	0 7262111 7262111 2.922 sec	0 6102074 6102074 3.970 sec
0 9783985 9783985 4.964 sec	0 8916097 8916097 3.074 sec	0 2596688 2596688 3.208 sec	0 8144331 8144331 4.192 sec	0 1172254 1172254 3.208 sec

FIGURE 10

Sample Test Results

One error was counted for each character that was incorrect, or omitted, or if an extra character was entered. The program could not determine if a character was omitted or an extra one entered, therefore if the string was one character off, they were all counted wrong by the program. This was corrected when the errors were tabulated by hand; a determination was made as to what type of error had occurred.

## RESULTS AND DISCUSSION

The data collected in the study was analyzed using a two way Analysis of Variance with repeated measures. Separate Analyses of Variance were run for each dependent variable: errors, sequence times, and list times. The model used for all Analyses of Variance were the same: conditions by days with repeated measures across days. Duncan's multiple range tests were performed for all main effects found significant by each Analysis of Variance.

Throughout this discussion, the 4X4 numeric keypad will be referred to as "the keypad." The conditions using the Microwriter with the original memory aids and without the aids will be referred to as "mnemonic" and "plain" respectively.

The research participants were randomly assigned to matched groups based on the skill level exhibited on the initial typing test. The categorization was three levels: high, medium, and low. The results of the test and the grouping can be seen in Table 1. The overall range for the typing test was 27.6 to 64.3 words per minute. Those typing above 40 words per minute were considered high skill, those typing below 30 words per minute were considered low skill. The operators whose scores fell between these boundaries were considered medium. The upper boundary reflects a natural break in the scores. The lower boundary was set rather arbitrarily by grouping the three lowest scores together. This grouping and balancing was done to control any tendency for experienced typists to do better on manual dexterity tasks than research participants inexperienced with conventional keyboards.

The discussion of the data gathered on the three dependent variables involved in the analysis: sequence time, list time, and errors, is better divided by group of tests, beginning or ending. This division forms a logical outline from which to discuss the results.

### Mean Times for Sequences

Letters: The mean times for each keyboard per day are shown in Figure 11. The actual values for the means are listed in Table 2. Initial inspection shows that on the first day's test, mnemonic started with a slightly higher mean (5.83 sec.) than the other two conditions (5.53 for keypad, 5.34 for plain). By the second day the keypad had the highest mean and remained in the top position. The corresponding Analysis of Variance for the test (Table 3), shows that neither condition nor the interaction of condition and days is significant. Again, "days" shows up as being significant. The Duncan Multiple Range test in Table 4 lists days 2, 3, and 4 as being significantly different from each other, while days 4 and 5 are not.

TABLE 1

Results of Typing Test: Means and Standard Deviations (all figures in words per minute)

	MNEMONIC	PLAIN	KEYPAD
LOW	28.0 wpm	29.6 wpm	27.6 wpm
MEDIUM	31.5 36.8 33.3	38.4 37.3 39.6	31.6 38.4 38.6
HIGH	58.5	64.3	58.3
AVERAGE	37.62	41.84	38.90
STANDARD DEVIATION	12.10	13.15	11.81

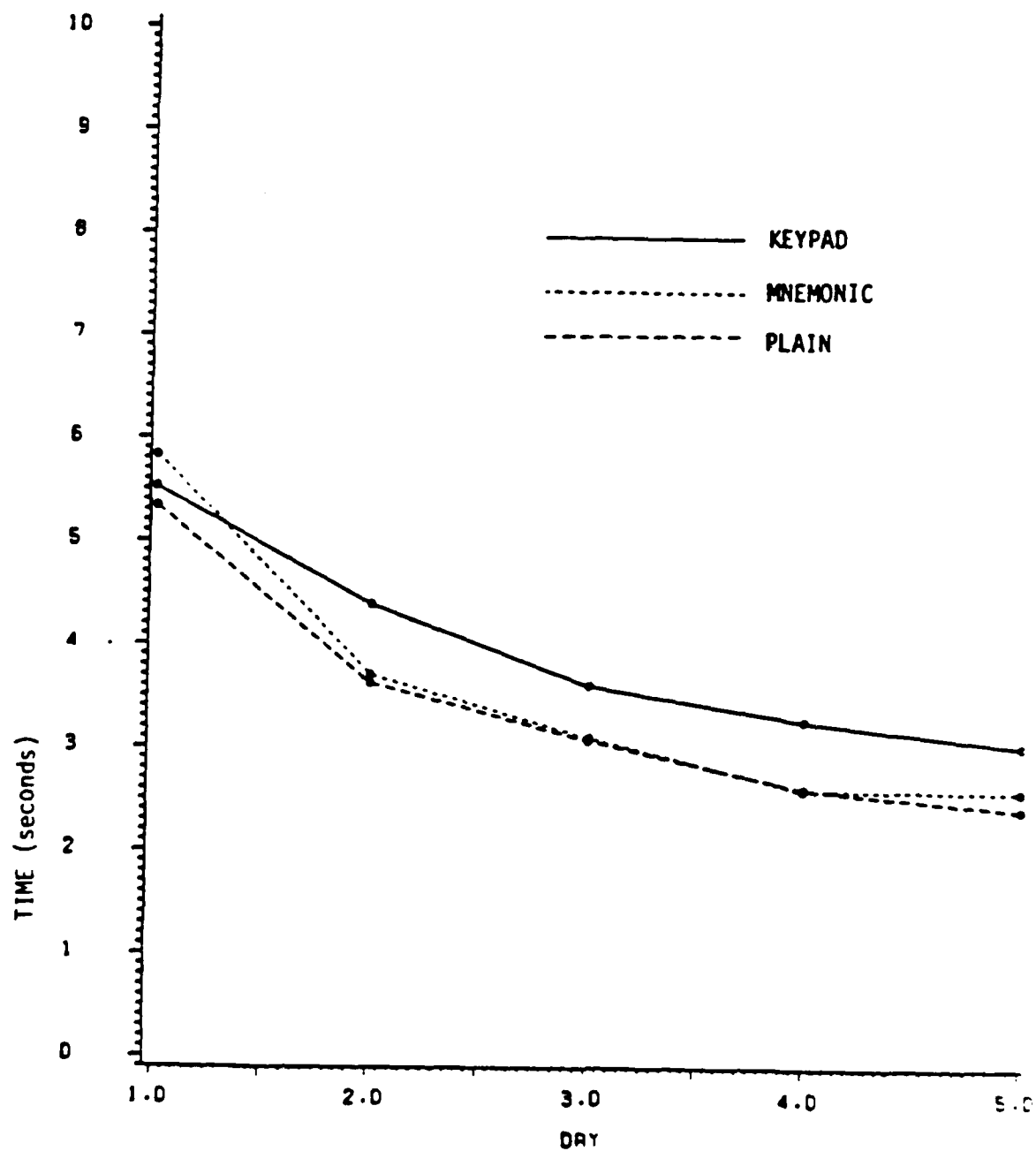


FIGURE 11

Mean Time by Condition Over Days for Letter Sequence Tests

TABLE 2

Means and Variances for Letter Sequence Times

		N	MEAN	VAR
CONDITI- ON	DAY			
KEYPAD	1	5	5.53	1.05
	2	5	4.39	0.73
	3	5	3.61	0.50
	4	5	3.27	0.26
	5	5	3.03	0.56
MNEMON	1	5	5.83	1.16
	2	5	3.71	0.88
	3	5	3.11	0.44
	4	5	2.59	0.18
	5	5	2.58	0.30
PLAIN	1	5	5.34	0.17
	2	5	3.63	0.38
	3	5	3.08	0.22
	4	5	2.61	0.26
	5	5	2.41	0.13
CONDITI- ON				
KEYPAD	ALL	25	3.97	1.37
MNEMON	ALL	25	3.56	2.01
PLAIN	ALL	25	3.41	1.34
	DAY			
ALL	1	15	5.57	0.72
	2	15	3.91	0.69
	DAY			
ALL	3	15	3.27	0.40
	4	15	2.82	0.31
	5	15	2.68	0.35
ALL	ALL	75	3.65	1.59

TABLE 3

## Analysis of Variance for Letter Sequence Times

Source	df	MS	F	PR>F
Condition	2	2.0431	1.04	0.3842
Day	4	20.6819	190.64	0.0001 *
Condition x Day	8	0.2141	1.97	0.0704
Error Subject(Condition)	12	1.9702		
Error Subject*Day(Condition)	48	0.1085		
Total	74	1.5862		

\* Significant at  $p < 0.05$

Table 4

Duncan's Multiple Range Test for Comparison of  
Days for Letter Sequence Times

Alpha = 0.05      df = 48      MSE = 0.10849

Grouping	Mean	N	Days
I	5.5664	15	1
I	3.9069	15	2
I	3.2658	15	3
I	2.8249	15	4
I	2.6762	15	5

**Numbers:** In Figure 12 there are the mean times for each condition; actual values are listed in Table 5. The difference between conditions is significant at the 0.05 level. The table on page 35 has the Duncan Multiple Range test for condition and it shows that pairs: mnemonic and plain, plain and keypad, are not significantly different. Mnemonic and keypad are shown to be different. The difference between days in the Analysis of Variance (Table 6) is shown to be highly significant; the corresponding condition and day interaction is also calculated as being significant to the 0.0001 level. Table 8 shows the Duncan Multiple range test for days.

#### **Mean Times for Lists**

**Letters:** Figure 13 shows the means by condition over days. The actual values for each point in the graph are listed in Table 9. The corresponding Analysis of Variance in Table 10 gives the predictable significant difference for days, but shows no significance for conditions or the interaction of condition and day. The pertinent Duncan Multiple Range test for days is listed in Table 11. Note that although not significant, the times for day 5 were longer than for day 4.

**Numbers:** The means of the sequence times for the number test are arranged by condition over days in Figure 14; the actual values for each point can be found in Table 12. The Analysis of Variance (Table 13) shows the usual high significance between days to the 0.0001 level; it also shows the same level of significance for the condition-day interaction term. The Duncan Multiple Range test in Table 14 indicates no significant difference for days 3, 4, and 5.

#### **Mean Errors**

**Letters:** Figure 15 shows the trend of each condition over time. Keypad, obviously has the lowest error rate, starting with 2.40 error on the first day and finishing with 0.20 errors on the fifth. The complete list of actual values can be found in Table 15. The Analysis of Variance (Table 16) shows condition to be significant beyond the 0.05 level. Day is also significant. In the Duncan's Multiple Range test for condition (Table 17), it is further determined that only keypad is significantly different from the other two. The Duncan's Multiple Range test for days appears in Table 18 and shows that only day one is significantly different.

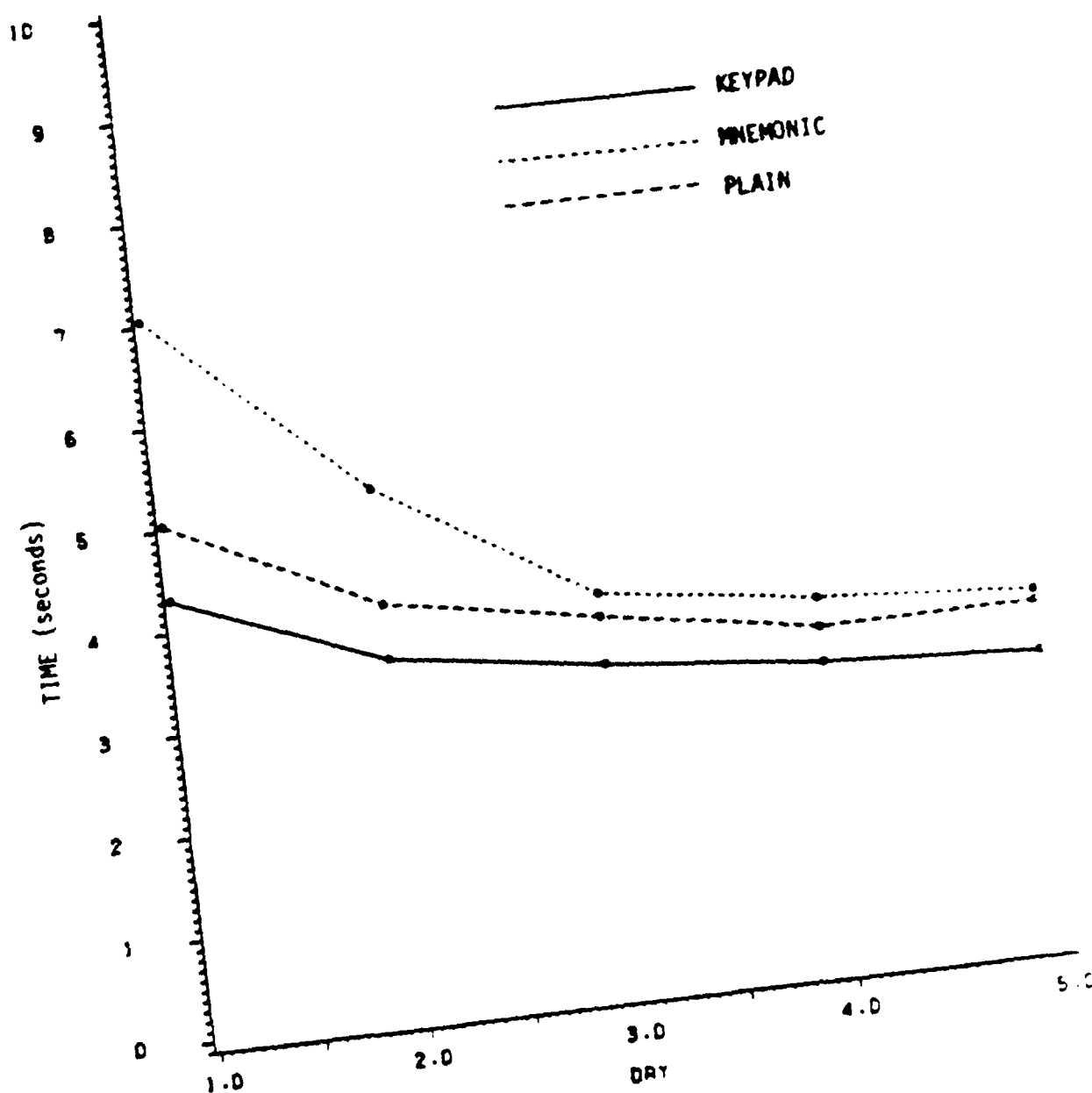


FIGURE 12  
Mean Time by Condition Over Days for Number Sequence Tests

TABLE 5

Means and Variances for Number Sequence Times

		N	MEAN	VAR
CONDITI- ON	DAY			
KEYPAD	1	5	4.31	1.78
	2	5	3.52	1.66
	3	5	3.23	1.31
	4	5	3.01	0.95
	5	5	2.88	1.19
MNEMON	1	5	7.05	1.18
	2	5	5.18	0.88
	3	5	3.91	0.21
	4	5	3.64	0.08
	5	5	3.48	0.08
PLAIN	1	5	5.04	0.11
	2	5	4.05	0.06
	3	5	3.68	0.17
	4	5	3.35	0.11
	5	5	3.37	0.07
CONDITI- ON				
KEYPAD	ALL	25	3.39	1.42
MNEMON	ALL	25	4.65	2.27
PLAIN	ALL	25	3.90	0.49
	DAY			
ALL	1	15	5.47	2.31
	2	15	4.25	1.26
	DAY			
ALL	3	15	3.61	0.57
	4	15	3.33	0.40
	5	15	3.25	0.46
ALL	ALL	75	3.98	1.63

TABLE 6

## Analysis of Variance for Number Sequence Times

Source	df	MS	F	PR>F
Condition	2	10.0846	4.00	0.0462 *
Day	4	12.6910	66.31	0.0001 *
Condition x Day	8	1.2895	6.74	0.0001 *
Error Subject(Condition)	12	2.5240		
Error Subject*Day(Condition)	48	0.1914		
Total	74	1.6314		

\* Significant at  $p < 0.05$

Table 7

Duncan's Multiple Range Test for Comparison of  
Conditions for Number Sequence Times

Alpha = 0.05      df = 12      MSE = 2.52396

Grouping	Mean	N	Condition
	4.6522	20	Mnemonic
	3.9016	20	Plain
	3.3894	20	Keypad

Table 8

Duncan's Multiple Range Test for Comparison of  
Days for Number Sequence Times

Alpha = 0.05      df = 48      MSE = 0.19138

Grouping	Mean	N	Days
1	5.4680	15	1
1	4.2502	15	2
1	3.6105	15	3
1	3.3304	15	4
1	3.2461	15	5

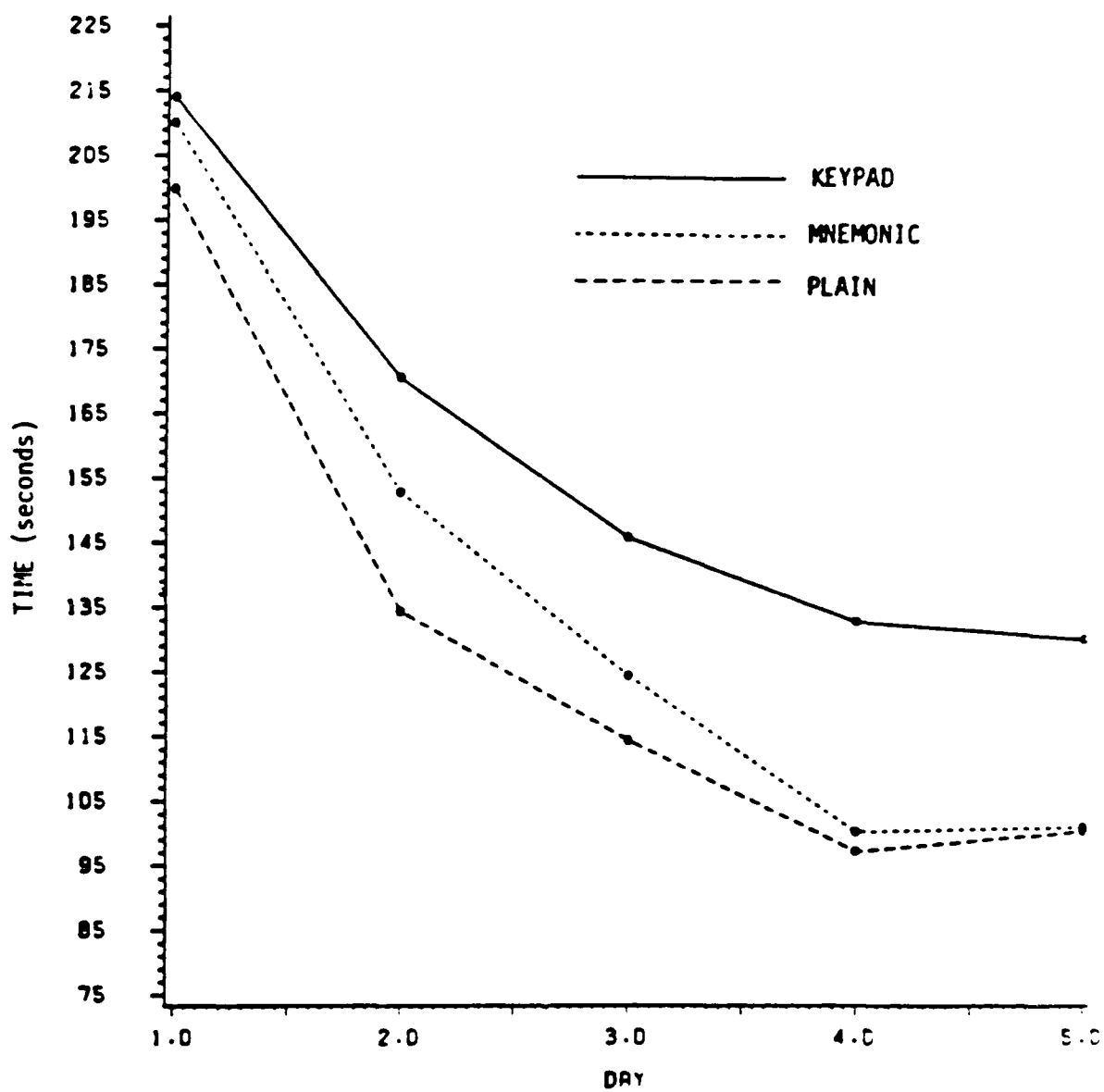


FIGURE 13

Mean Time by Condition Over Days for Letter List Tests

TABLE 9

Means and Variances for Letter List Times

		N	MEAN	VAR
CONDITI- ON	DAY			
KEYPAD	1	5	214.00	789.50
	2	5	170.60	924.30
	3	5	145.80	492.70
	4	5	132.80	29.70
	5	5	130.20	193.20
MNEMON	1	5	210.00	1042.5
	2	5	152.80	2486.2
	3	5	124.40	1036.8
	4	5	100.20	196.70
	5	5	101.00	340.50
PLAIN	1	5	199.80	170.70
	2	5	134.40	298.30
	3	5	114.40	358.80
	4	5	97.20	357.70
	5	5	100.40	149.30
CONDITI- ON				
KEYPAD	ALL	25	158.68	1415.1
MNEMON	ALL	25	137.68	2597.4
PLAIN	ALL	25	129.24	1698.3
	DAY			
ALL	1	15	207.93	610.50
	2	15	152.60	1293.7
	DAY			
ALL	3	15	128.20	723.31
	4	15	110.07	445.35
	5	15	110.53	402.41
ALL	ALL	75	141.87	2007.4

TABLE 10

## Analysis of Variance for Letter List Times

Source	df	MS	F	PR>F
Condition	2	5745.6134	2.83	0.0982
Day	4	29474.453	107.63	0.0001 *
Condition x Day	8	211.8467	0.91	0.5140
Error Subject(Condition)	12	2027.4533		
Error Subject*Day(Condition)	48	232.0450		
Total	74	2007.4414		

\* Significant at  $p < 0.05$

Table 11

Duncan's Multiple Range Test for Comparison of  
Days for Letter List Times

Alpha = 0.05      df = 48      MSE = 232.045

Grouping	Mean	N	Days
I	207.93	15	1
I	152.60	15	2
I	128.20	15	3
I	110.53	15	5
I	110.07	15	4

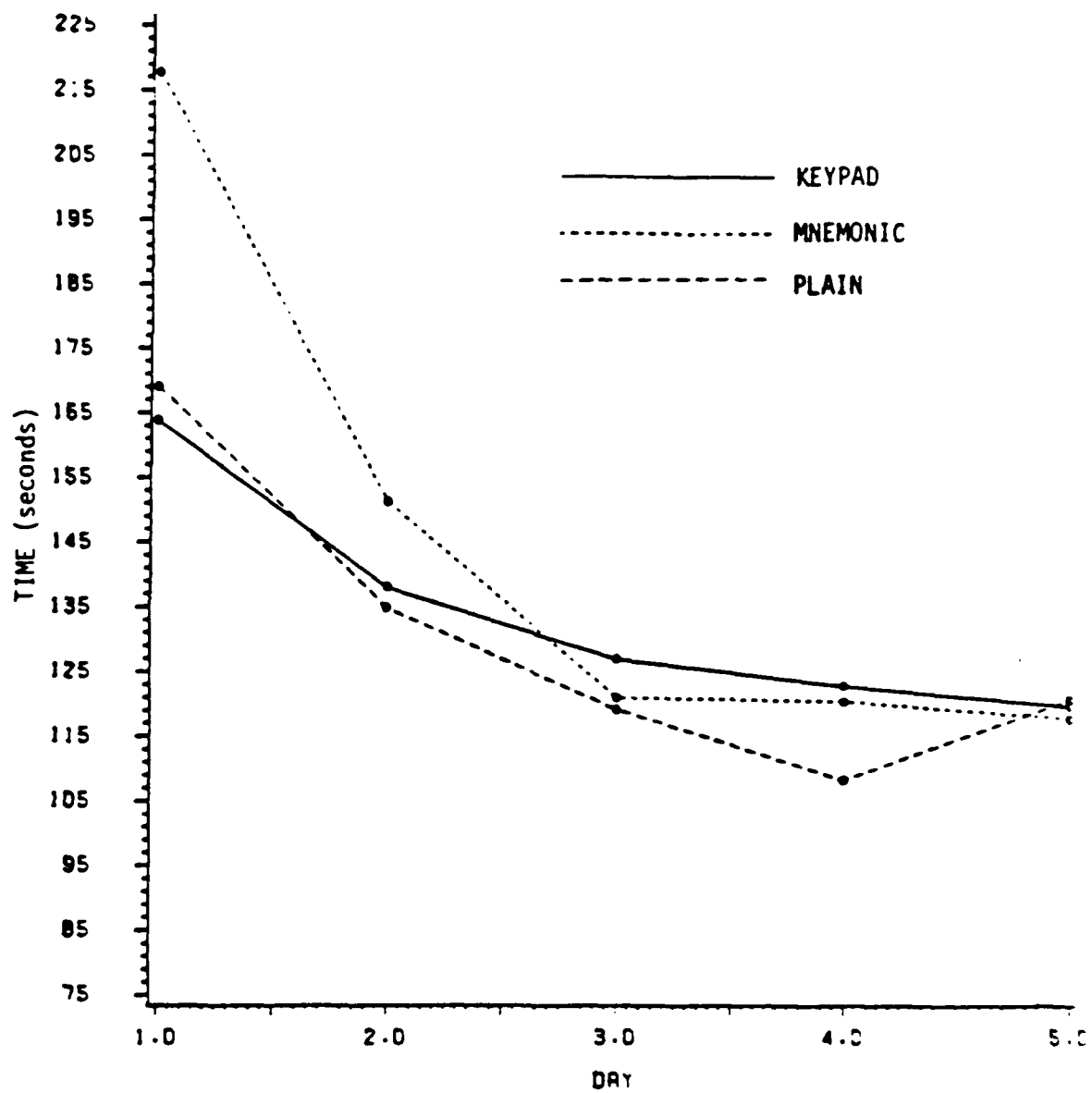


FIGURE 14

Mean Time by Condition Over Days for Number List Tests

TABLE 22

Means and Variances for Number List Times

		N	MEAN	VAR
CONDITI- ON	DAY			
KEYPAD	1	5	163.80	1152.2
	2	5	138.00	1164
	3	5	127.00	1272.5
	4	5	122.80	1018.7
	5	5	119.80	1171.7
MNEMON	1	5	217.60	591.30
	2	5	151.20	1033.2
	3	5	121.00	316.00
	4	5	120.40	94.80
	5	5	117.80	338.70
PLAIN	1	5	169.00	57.50
	2	5	134.80	47.20
	3	5	119.20	105.70
	4	5	108.20	65.20
	5	5	120.80	222.70
CONDITI- ON				
KEYPAD	ALL	25	134.28	1229.8
MNEMON	ALL	25	145.60	1901.6
PLAIN	ALL	25	130.40	545.50
	DAY			
ALL	1	15	183.47	1143.6
	2	15	141.33	695.24
	DAY			
ALL	3	15	122.40	425.97
	4	15	117.13	380.55
	5	15	119.47	496.84
ALL	ALL	75	136.76	1234.6

TABLE 13

## Analysis of Variance for Number List Times

Source	df	MS	F	PR>F
Condition	2	1559.6400	0.69	0.5197
Day	4	11598.386	73.80	0.0001 *
Condition x Day	8	905.7367	5.76	0.0001 *
Error Subject(Condition)	12	2255.1200		
Error Subject*Day(Condition)	48	157.1700		
Total	74	1234.6443		

\* Significant at  $p < 0.05$

Table 14

Duncan's Multiple Range Test for Comparison of  
Days for Number List Times

Alpha = 0.05      df = 48      MSE = 157.17

Grouping	Mean	N	Days
1	183.47	15	1
1	141.33	15	2
1	122.40	15	3
1	119.47	15	4
1	117.13	15	5

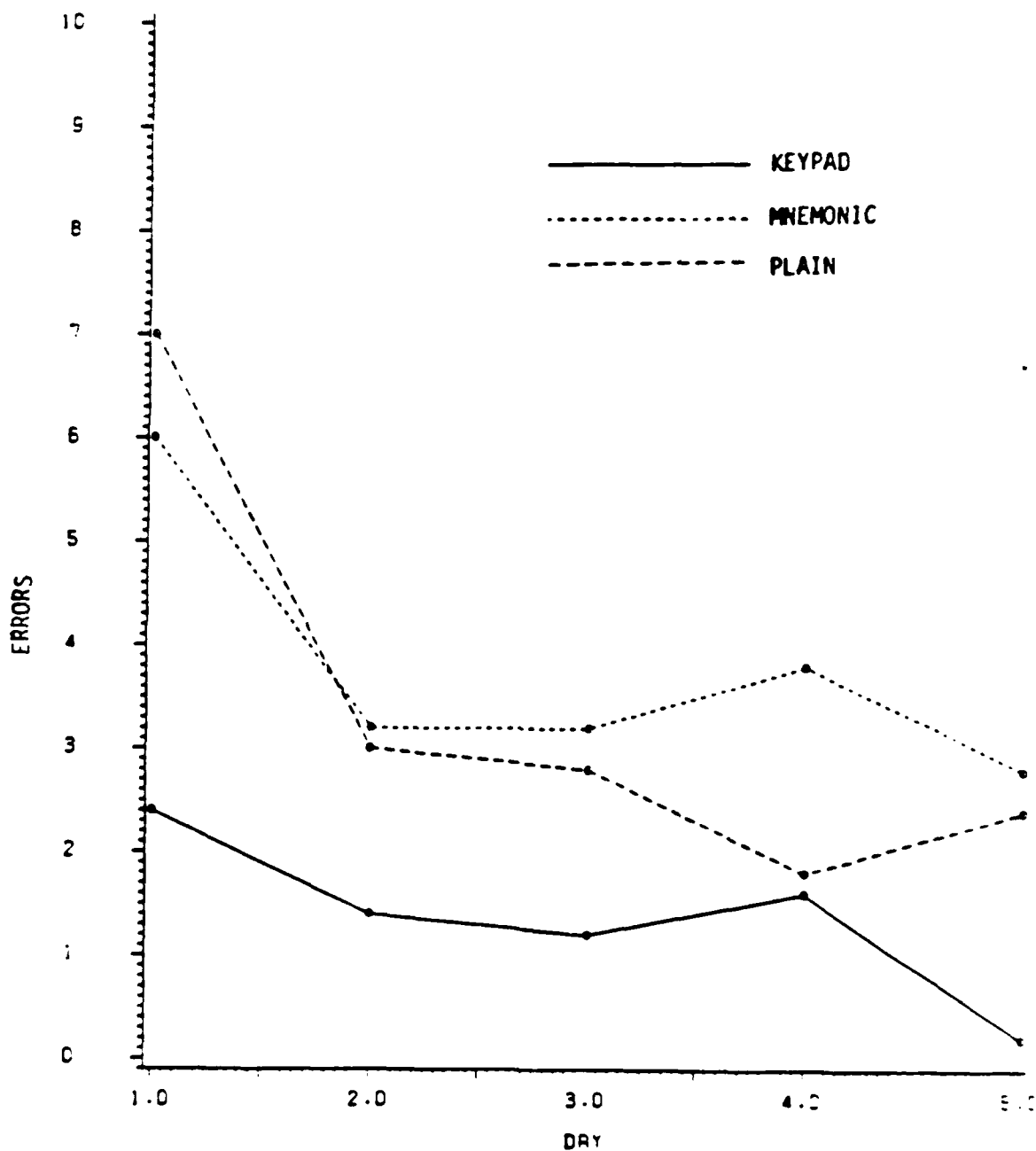


FIGURE 15

Mean Error by Condition Over Days for Letter Tests

TABLE 15

Means and Variances for Letter Error Count

		N	MEAN	VAR
CONDTI- ON	DAY			
KEYPAD	1	5	2.40	11.30
	2	5	1.40	2.80
	3	5	1.20	0.70
	4	5	1.60	0.80
	5	5	0.20	0.20
MNEMON	1	5	6.00	6.50
	2	5	3.20	3.70
	3	5	3.20	8.20
	4	5	3.80	28.70
	5	5	2.80	3.70
PLAIN	1	5	7.00	12.50
	2	5	3.00	8.50
	3	5	2.80	4.70
	4	5	1.80	0.70
	5	5	2.40	0.30
CONDTI- ON				
KEYPAD	ALL	25	1.36	3.16
MNEMON	ALL	25	3.80	9.83
PLAIN	ALL	25	3.40	8.00
	DAY			
ALL	1	15	5.13	12.84
	2	15	2.53	4.98
	DAY			
ALL	3	15	2.40	4.69
	4	15	2.40	9.69
	5	15	1.80	2.60
ALL	ALL	75	2.85	7.96

TABLE 16

## Analysis of Variance for Letter Error Count

Source	df	MS	F	PR>F
Condition	2	42.8133	3.95	0.0482 *
Day	4	25.5800	5.05	0.0018 *
Condition x Day	8	3.5300	0.70	0.6922
Error Subject(Condition)	12	10.8467		
Error Subject*Day(Condition)	48	5.0633		
Total	74	7.9647		

\* Significant at  $p < 0.05$

Table 17

Duncan's Multiple Range Test for Comparison of  
Conditions for Letter Error Count

Alpha = 0.05      df = 12      MSE = 10.8467

Grouping	Mean	N	Condition
1	3.8000	20	Mnemonic
2	3.4000	20	Plain
3	1.3600	20	Keypad

Table 18

Duncan's Multiple Range Test for Comparison of  
Days for Letter Error Count

Alpha = 0.05    df = 48    MSE = 5.06333

Grouping	Mean	N	Days
1	5.1333	15	1
2	2.5333	15	2
3	2.4000	15	4
4	2.4000	15	3
5	1.8000	15	5

**Numbers:** Figure 16 and Table 19 come from the data for the error count on the numbers test. The Analysis of Variance (Table 20) shows condition and day as significant and the interaction term approaching significance. The Duncan Multiple Range tests for conditions and days are listed in Table 21 and 22 respectively. Of note, but not statistically significant, is the fact that the days are not in the regular chronological order. Days 3, 4, and 5 are reversed but are not significantly different from one another.

#### **Confusion Errors**

Table 23 shows which letters were confused with other letters for the two chord keypad conditions. Since there were four letters in each sequence and 25 sequences in each list, a letter should occur an average of approximately four times in each list. The list was presented to the research participant five times meaning that the participant would have an opportunity to enter a particular letter 20 times over the course of the experiment. If a letter was put in place of another letter four or more times it appears in the table. This is an error rate of 20 percent or more. For example, the letter 'D' was entered in place of the letter 'C' more than four times by the subjects in the plain condition. As is shown by the chart only two letters appear in both conditions, those are the letter 'F' being entered instead of the letter 'D' and 'Z' instead of 'Q'.

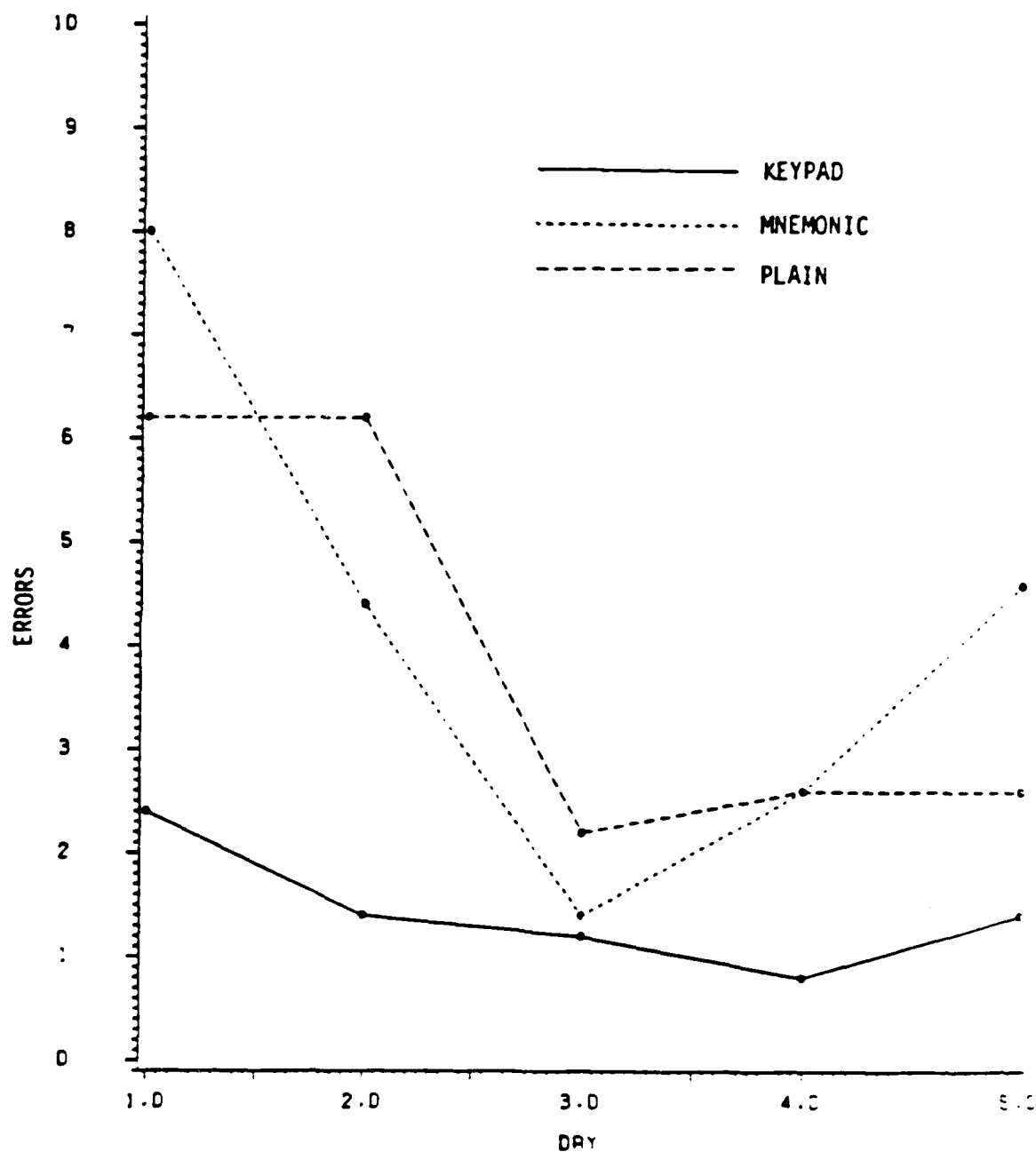


FIGURE 16

Mean Error by Condition Over Days for Number Tests

		N	MEAN	VAR
CONDITI- ON	DAY			
KEYPAD	1	5	2.40	5.30
	2	5	1.40	2.80
	3	5	1.20	0.20
	4	5	0.80	0.70
	5	5	1.40	1.30
MNEMON	1	5	8.00	16.50
	2	5	4.40	15.30
	3	5	1.40	2.30
	4	5	2.60	2.80
	5	5	4.60	4.80
PLAIN	1	5	6.20	8.20
	2	5	6.20	9.20
	3	5	2.20	1.20
	4	5	2.60	8.80
	5	5	2.60	0.80
CONDITI- ON				
KEYPAD	ALL	25	1.44	2.01
MNEMON	ALL	25	4.20	12.17
PLAIN	ALL	25	3.96	8.21
	DAY			
ALL	1	15	5.53	14.41
	2	15	4.00	12.00
	DAY			
ALL	3	15	1.60	1.26
	4	15	2.00	4.29
	5	15	2.87	3.84
ALL	ALL	75	3.20	8.84

TABLE 19

Means and Variances for Number Error Count

TABLE 20

## Analysis of Variance for Number Error Count

Source	df	MS	F	PR>F
Condition	2	58.4400	5.59	0.0193 *
Day	4	38.2333	9.40	0.0001 *
Condition x Day	8	63.3867	1.95	0.0742
Error Subject(Condition)	12	10.4600		
Error Subject*Day(Condition)	48	4.0683		
Total	74	8.8378		

\* Significant at  $p < 0.05$

Table 21

Duncan's Multiple Range Test for Comparison of  
Conditions for Number Error Count

Alpha = 0.05      df = 12      MSE = 10.46

Grouping	Mean	N	Condition
	4.2000	20	Mnemonic
	3.9600	20	Plain
	1.4400	20	Keypad

Table 22

Duncan's Multiple Range Test for Comparison of  
Days for Number Error Count

Alpha = 0.05      df = 48      MSE = 4.06833

Grouping	Mean	N	Days
1	5.5333	15	1
2	4.0000	15	2
3	2.8667	15	5
4	2.0000	15	4
5	1.6000	15	3

TABLE 23

Confusion Matrix:  
Matrix of letters which were entered more than four times incorrectly for a particular letter.

Correct entry	A	B	C	D	E	F	G
INCORRECT ENTRIES							
Mnemonic:				BF			
Plain:		M	D	FY			

Correct entry	H	I	J	K	L	M	N
INCORRECT ENTRIES							
Mnemonic:			J				
Plain:		L			R		Y

Correct entry	U	P	Q	R	S	T	U
INCORRECT ENTRIES							
Mnemonic:			VZ				
Plain:			Z				

Correct entry	V	W	X	Y	Z
INCORRECT ENTRIES					
Mnemonic:	LQ				
Plain:		P			

## CONCLUSIONS AND RECOMMENDATIONS

To summarize, neither keypad, given the constraints of training and practice time, was found to be superior in terms of speed. The 4X4 keypad was however, found to have significantly less errors than the Microwriter. The second objective of the study dealt with the difference in errors due to the use or non-use of the memory aids. There was slight evidence to show that mnemonics increases the number of errors. Confusion between different letters occurred by the use or nonuse of the memory aids.

The third objective dealt with an arbitrarily set level of proficiency to be gained on the various keypads. This was set at 50% of the average speed demonstrated on the beginning QWERTY typing test. The average speed was calculated to be 39.45 words per minute or 197.25 characters per minute. The 50% level would therefore be 98.63. This level was not gained on any of the conditions. The 25% level, however, was attained by all conditions (see Table 24).

For the fourth objective of this study, it was found that slight practice on the 4X4 keypad does show improvement in performance, at least during the first four days. There was some evidence that a plateau of behavior was exhibited during the fifth day.

Given the short time each operator had in training (2.5 hours during five days) neither Microwriter or 4X4 keypad shows a really definite advantage in terms of speed. On the test for numbers, condition is shown to be significant beyond the 0.05 level (Table 6). Upon inspection of Figure 12 it can be seen that it is the mnemonic condition which caused the difference by having such relatively high times for the first two days. The difference is gone by the third day, the line converging with the rest. This convergence gives rise to the significant interaction term.

Figures 17 and 18 show the overall means by condition for sequence times. In these figures, it is apparent that there is very little difference in times. The keypad tends to show an enlarged difference in comparison to the conditions on the Microwriter when tested with numbers but it was still not significant. Figures 19 and 20 are bar charts showing the overall means by condition for list times. Again visible is the tendency (nonsignificant) for keypad to take longer for letters and shorter for numbers. This is not surprising since it takes two separate and distinct keypresses and even a visual search for the correct key in order to get one letter. It was expected that the keypad would take a much shorter time for keying because of the familiarization with the keyboard that all

TABLE 24

Data Entry Rates by Condition and by Type of Test

DATA ENTRY RATES		(ALL FIGURES IN CHARACTERS PER MINUTE)					
		SEQUENCE			LIST		
		BEGIN	END	AVERAGE	BEGIN	END	AVERAGE
KEYPAD	ALPHA	73.2	79.2	76.2	46.2	46.1	46.1
	NUMERIC	80.8	83.3	82.1	50.9	50.1	50.5
	AVERAGE	77.0	81.2	79.1	48.5	48.1	48.3
MNEMONIC	ALPHA	83.6	93.0	88.3	57.7	59.4	58.6
	NUMERIC	66.3	69.0	67.6	51.0	50.9	51.0
	AVERAGE	75.0	81.0	78.0	54.4	55.2	54.8
PLAIN	ALPHA	88.9	99.6	94.2	60.4	59.8	60.1
	NUMERIC	71.4	71.2	71.3	54.6	49.7	52.2
	AVERAGE	80.2	85.4	82.8	57.5	54.7	56.1

research participants had. Expectations were that the more familiar with the phone, the faster the person should be.

Where the keyboards differ greatly is in terms of errors. Condition is significant in both of the Analyses of Variance for error. In each (Tables 16 and 20), condition is significant to beyond the 0.05 level. The corresponding Duncan tests (Tables 17 and 21) register keypad differently than the other two conditions. The keypad had fewer errors at the end. It is of note that there is an absence of a significant interaction term in both, yet the relevant graphs, (Figures 15 and 16 respectively) show many changes in angle of the lines.

Looking at Figure 21 which has the overall error means by condition for letter tests it is seen that keypad has a smaller error rate than the other two. For the numbers tests, Figure 22 is of importance. In both analyses, the keypad was found to have significantly less errors than both of the Microwriter conditions.

For the confusion of letters for the chord keypad, only two letters appear in both conditions as being confused with the same letter four or more times in each condition. From this it is evident that the use or nonuse of the memory aids does lead to different errors.

All research participants were able to become familiar with all of the chords within the first session. The sequence time values of the first test given (when most chords were not learned and extensive use of the cue card was necessary) should give an indication of the difference in search time for the two conditions. Looking at the proper figures and tables (tests for the first day: Figures 11 and 12, and Tables 2 and 5), searching for the correct chord does not seem to be a problem for letters and only marginally for the numbers.

Entry rate on the keypad improved marginally over the duration of the study. As shown in the various interaction graphs (Figures 17 through 20) all keypad lines have a general downward trend. All Analyses of Variance dealing with time values have day as significant, although whether this is significant for just keypad is doubtful. A follow-up study readily suggests itself at this point.

Relying on these conclusions, chord keyboards of the handprint type tested here should not be used in applications which do not warrant long training times. Applications which cannot provide a large amount of training and which also have severe consequences for errors should not use a handprint chord keyboard. The 4x4 keypad should be used only in those situations which require infrequent and brief entry. It is possible that a 4x4 keypad could be used in a heads-up data entry task, but only after a long period of training. Further study is needed to ascertain how feasible this is, and whether other encoding methods would work better.

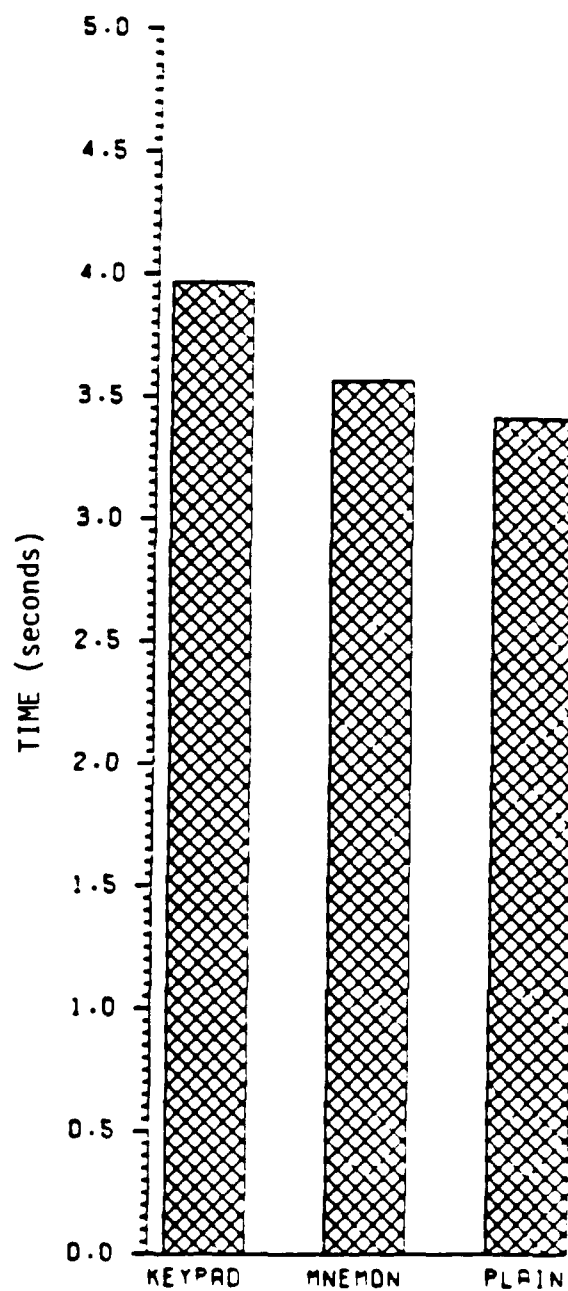


Figure 17  
Comparison of Mean Sequence Encoding Times Between  
Conditions on Letter Tests

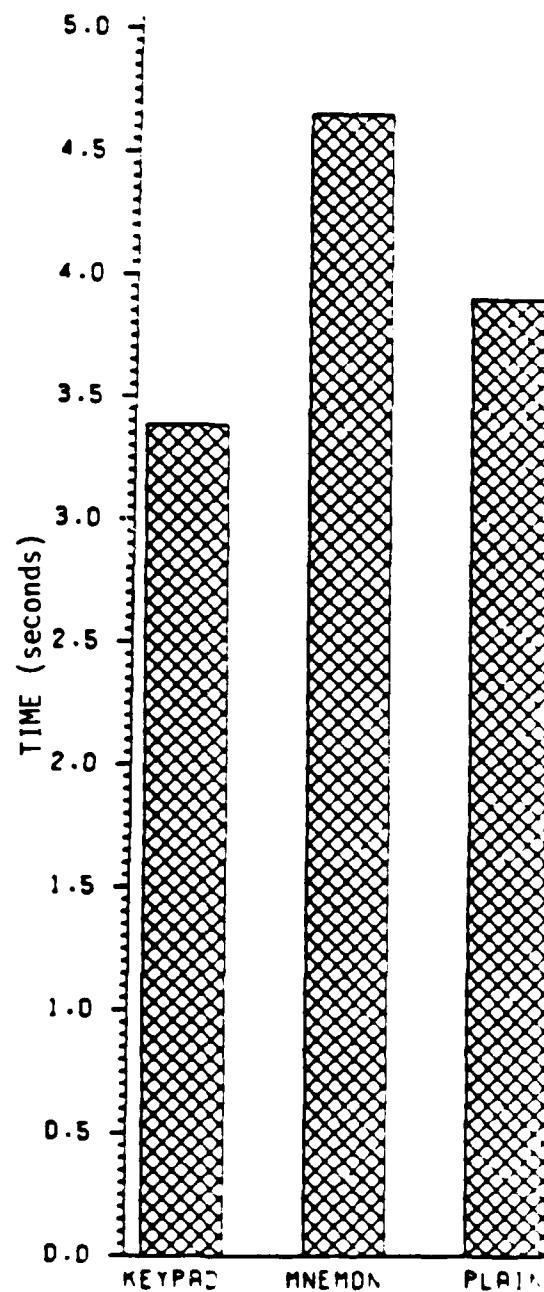


Figure 13

Comparison of Mean Sequence Encoding Times Between  
Conditions on Number Tests

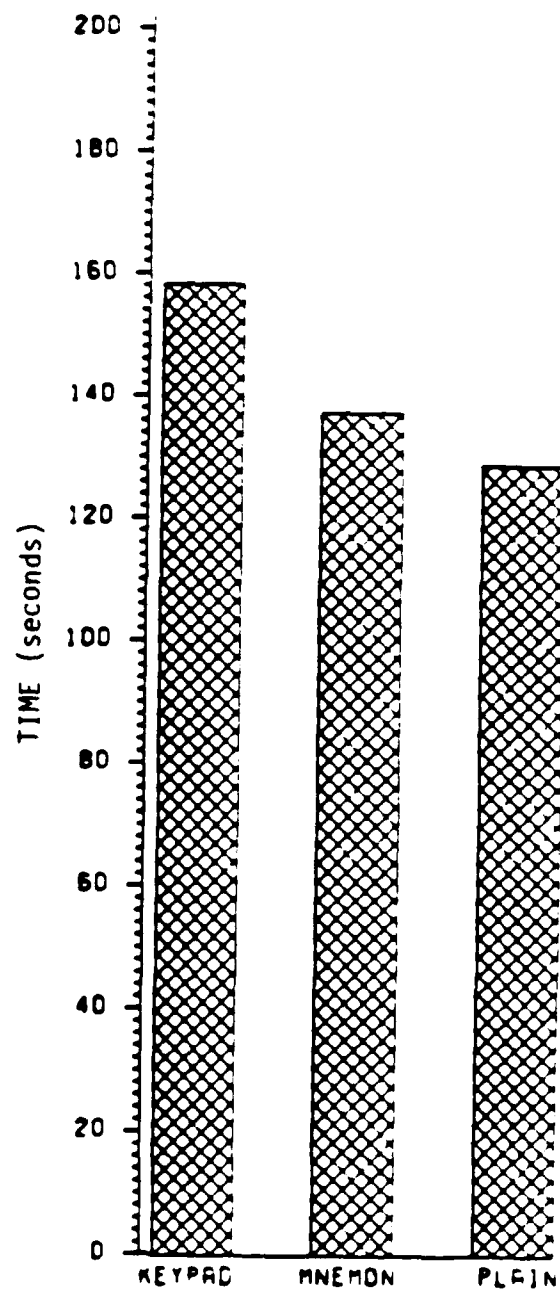


Figure 19  
Comparison of Mean List Encoding Times Between  
Conditions on Letter Tests

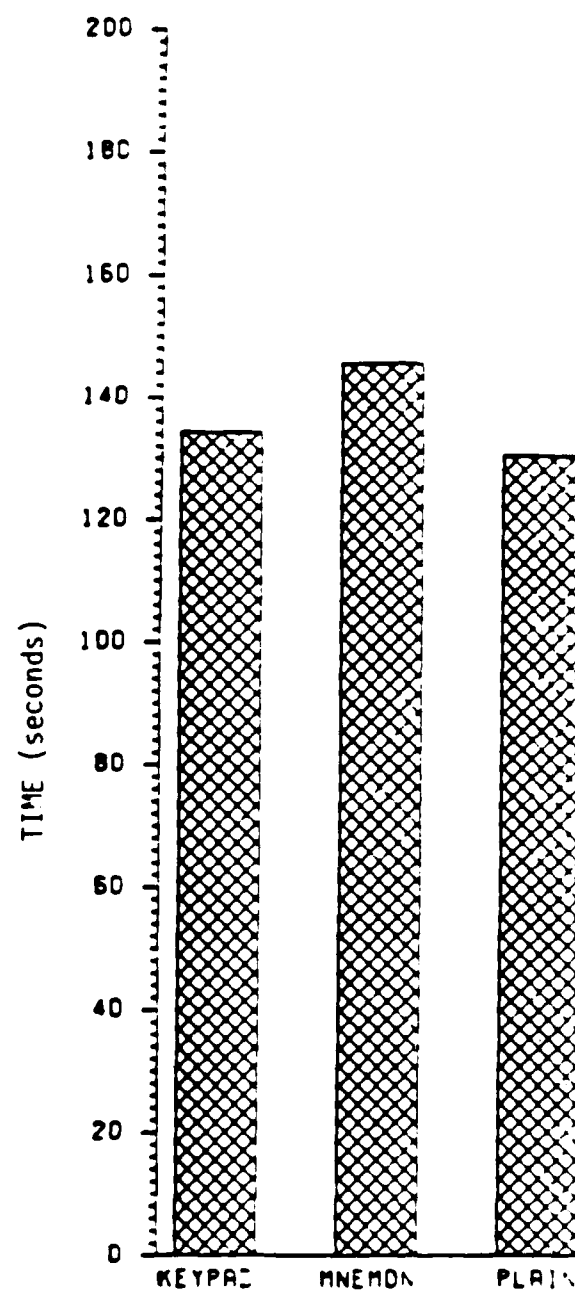


Figure 20  
Comparison of Mean List Encoding Times Between  
Conditions on Number Tests

beyond the 0.05 level. The corresponding Duncan tests (Tables 17 and 21) register keypad differently than the other two conditions. The keypad had fewer errors at the end. It is of note that there is an absence of a significant interaction term in both, yet the relevant graphs, (Figures 15 and 16 respectively) show many changes in angle of the lines.

Looking at Figure 21 which has the overall error means by condition for letter tests it is seen that keypad has a smaller error rate than the other two. For the numbers tests, Figure 22 is of importance. In both analyses, the keypad was found to have significantly less errors than both of the Microwriter conditions.

For the confusion of letters for the chord keypad, only two letters appear in both conditions as being confused with the same letter four or more times in each condition. From this it is evident that the use or nonuse of the memory aids does lead to different errors.

All research participants were able to become familiar with all of the chords within the first session. The sequence time values of the first test given (when most chords were not learned and extensive use of the cue card was necessary) should give an indication of the difference in search time for the two conditions. Looking at the proper figures and tables (tests for the first day: Figures 11 and 12, and Tables 2 and 5), searching for the correct chord does not seem to be a problem for letters and only marginally for the numbers.

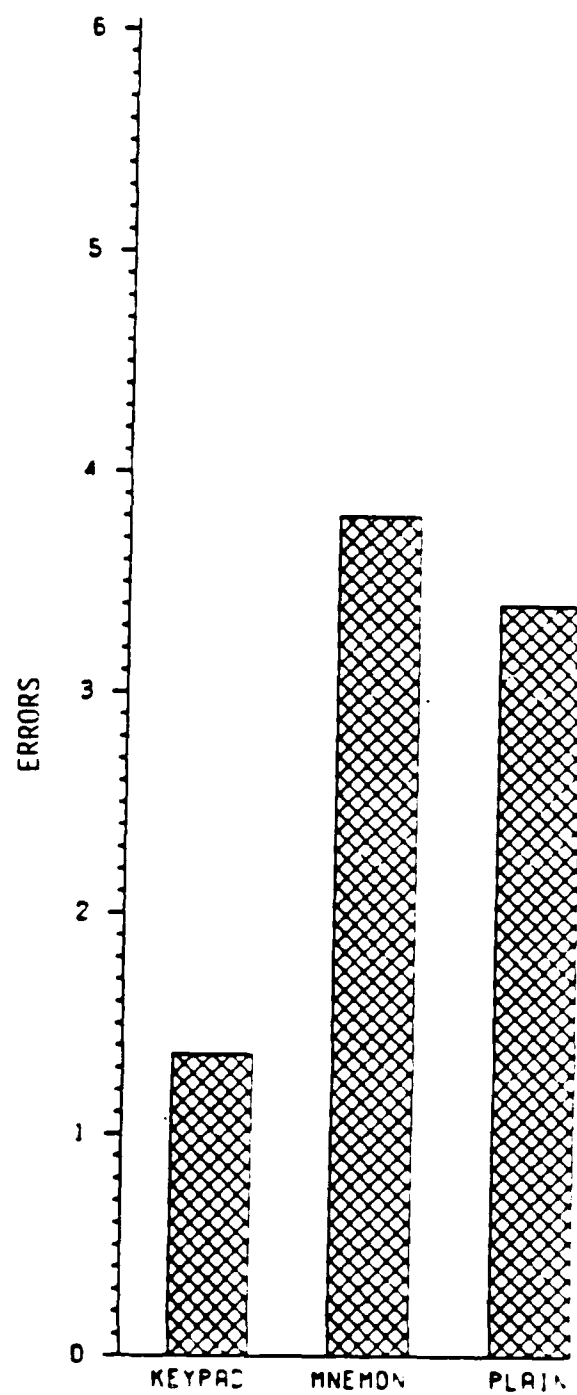


Figure 21  
Comparison of Mean Errors Between Conditions  
on Letter Tests

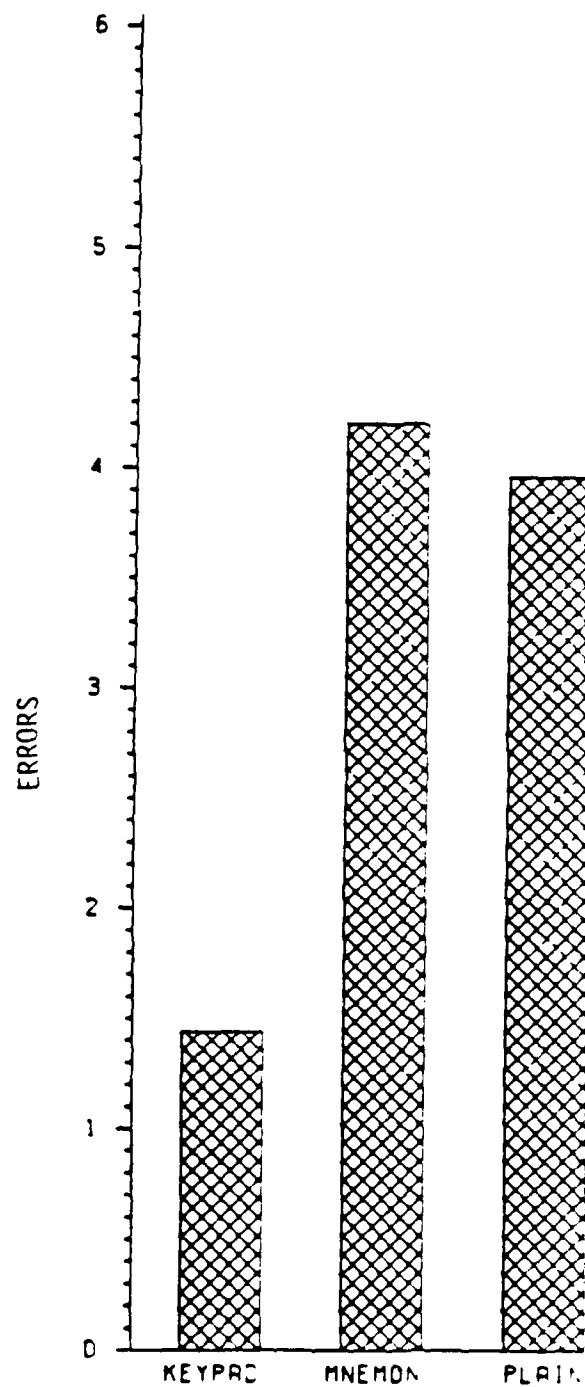


Figure 22  
Comparison of Mean Errors Between Conditions  
on Number Tests

A number of other follow-up studies and related studies are suggested by the research documented here. Starting with the results of the QWERTY skills test which was used for classification of research participants into groups, but was otherwise unused in the final analysis, a study should be done to investigate transfer effects between the conventional typewriter and different types of chord keyboards. The question of whether skill on a QWERTY board or the manual dexterity involved has an effect on beginner chord users can be investigated using skilled typists and accomplished pianists.

Due to the limited amount of time at the keyboard that volunteers were willing to endure, asymptotic behavior was not reached although a plateau to speed was. A longer study using longer practice sessions, a longer span of days or both should be done to establish a learning curve for both keyboards, the upper limits to speed, and if the chord keyboard actually meets performance claims made by the manufacturer. Research participants for this study would have to have some external motivation greater than the intrinsic rewards available in this study.

The effects of different activation force curves for the keys and different key technologies, different curvatures of the palm rest and even an adjustable palm rest should all be investigated to make the chord keyboard more acceptable to the novice user. Retention of skill over weeks or even months for relatively long time users would make another good study.

The use of various operator populations also lends itself to study. The chord keyboard has been integrated into control columns of certain aircraft for in-flight data entry. Keying ability under workload or stress, with gloves, and in various acceleration environments such as those found in military aviation should be investigated with chord keyboards.

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## APPENDIX A

### COPY OF TEXT USED FOR TYPING TEST

#### Exercise 161

From the common-sense standpoint, everyone understands, or considers that he understands, what is meant by time or duration; but an appreciation of its real nature, with its assumed infinite duration in the past and its infinity in the future, has always baffled the philosopher. According to Newton, absolute, true and mathematical time, by itself, flows uniformly on without respect to anything external. He thus conceived time as something which would continue even if there were no other physical phenomena, no material bodies, and no human being in existence. No method, however, can be imagined whereby such absolute time could be directly measured, and it is clear that for time measurement it is necessary to consider other physical changes in addition to time itself.

The change with which time can be most conveniently associated for this purpose is motion, and time-measurement is based upon the observation of a standard uniform motion, the rotation of the earth on its axis being that actually employed.

The theory of relativity, with which Einstein's name is associated, has for long attracted considerable attention, and it includes an idea of time quite different from that enunciated by Newton. According to this theory, there is no universal absolute time, and the measurements of both time and length will vary with the motion of the observer making the measurements. Two observers on different moving systems will fail to agree as to what constitutes equal periods of time or equal lengths of bodies, and they will not always agree as to whether two events occur simultaneously or otherwise even after adjustments have been made for the time taken by light to travel from the observed bodies to the observers. Measurements of the velocity of light, however, give the same result for both observers. The differences between the measurements of time and length by the two observers are wholly inappreciable for motions relative to one another which come within the range of human experience, and no practical difficulties, in connection with clocks and watches, arise from this theory.

The rotation of the earth, upon which practical time measurement is based, is determined by the apparent motions of the heavenly bodies, and some acquaintance with astronomical principles is necessary to appreciate the methods employed.

Although the stars are at different distances from the earth, they can all be imagined as projected upon a sphere of which the earth forms the centre.

#### *Strokes*

68  
143  
217  
290  
362  
435  
498  
565  
633  
709  
771  
842  
914  
989  
1007  
1078  
1152  
1226  
1300  
1373  
1444  
1519  
1594  
1669  
1744  
1817  
1885  
1959  
2034  
2082  
2149  
2221  
2293  
2314  
2388  
2463

1493 words

APPENDIX B  
ALL PROGRAMS USED IN EXPERIMENT

# TEST.MAIN

```

10 DIM A$(25),A1$(25),A2$(25),A3
   $(25),A4$(25)
20 RD = - 16384:CL = - 16368
30 D$ = CHR$(13) + CHR$(4)
40 TEXT : HOME : VTAB 8
50 PRINT "[1] ENTRY OF DATA"
60 PRINT "[2] EDITING OF DATA"
70 PRINT
80 PRINT "[3] TESTING PROCESS"
90 PRINT "[4] PRACTICE SESSION"
100 PRINT
110 PRINT "[5] PRINT DATA"
120 PRINT "[6] PRINT RESULTS"
130 PRINT
140 PRINT "[7] EXIT TO SYSTEM PR
    UMPT"
150 VTAB 20
160 PRINT "PLEASE CHOOSE (1-7) :
    ";
170 GET Z$: PRINT Z$
180 IF VAL (Z$) < 1 OR VAL (Z$
    ) > 7 THEN 40
190 ON VAL (Z$) GOTO 220,200,48
    0,210,600,790,1340
200 PRINT D$;"RUN TEST.EDIT"
210 PRINT D$;"RUN TEST.PRACTICE"

220 REM

```

## ENTRY OF DATA

```

230 GOSUB 1540
240 HOME : VTAB 5: HTAB 11
250 PRINT "PLEASE INPUT DATA"
260 VTAB 8
270 FOR X = 1 TO 12
280 PRINT SPC( (X < 10));X;" "
    ;
290 INPUT "";A$(X)
300 NEXT X
310 FOR X = 13 TO 25
320 VTAB X - 5: HTAB 20
330 PRINT X;" "
340 INPUT "";A$(X)
350 NEXT X

```

```

360 ONERR GOTO 1460
370 PRINT D$;"OPEN "TS$";L20"
380 PRINT D$;"READ "TS$";R0"
390 INPUT REC
400 FOR X = 1 TO 25
410 PRINT D$;"WRITE "TS$";R";REC
    + X
420 PRINT A$(X)
430 NEXT X
440 PRINT D$;"WRITE "TS$";R0"
450 PRINT REC + 25
460 PRINT D$;"CLOSE "TS$
470 GOTO 40
480 REM

```

#### TESTING PROCESS

```

490 HOME
500 VTAB 12
510 PRINT "1. TEST WITH KEYBOARD
"
520 PRINT "2. TEST WITH MICROWRI
TER"
530 PRINT
540 PRINT "PLEASE CHOOSE (1/2) :
";
550 GET Z$: PRINT Z$
560 IF VAL (Z$) < 1 OR VAL (Z$
) > 4 THEN 490
570 ON VAL (Z$) GOTO 580,590
580 PRINT D$;"RUN TEST.KEYBOARD"

590 PRINT D$;"RUN TEST.MICRO"
600 REM

```

#### PRINT DATA

```

610 HOME
620 GOSUB 1540
630 VTAB 12
640 INPUT "PRINTER SLOT :";PR
650 PRINT D$;"PR#";PR
660 PRINT D$;"OPEN "TS$";L20"
670 PRINT D$;"READ "TS$";R0"
680 INPUT REC
690 FOR X = 1 TO REC
700 PRINT D$;"READ "TS$";R";X

```

```

710 INPUT A$
720 PRINT SPC( (X < 10));X;". ";
    A$;
730 IF PR = 0 THEN FOR C = 1 TO
    500: NEXT C
740 NEXT X
750 PRINT D$;"CLOSE "TSS
760 PRINT D$;"PR#U"
770 PRINT : PRINT "PLEASE PRESS
    ANY KEY TO CONTINUE";: WAIT
    RD,128: POKE CL,0
780 GOTO 40
790 REM

```

# PRINT RESULTS

```

800 HOME
810 VTAB 12
820 INPUT "PRINTER SLOT :";PR
822 PRINT "PRINT ONE FILE OR ALL
    (1/A) :";
824 GET Q$: PRINT Q$
826 IF Q$ < > "1" AND Q$ < > "
    A" THEN VTAB 13: GOTO 822
828 IF Q$ = "1" THEN 1332
830 DIM TSS(255)
840 PRINT D$;"OPEN TEST.RESULTS"

850 PRINT D$;"READ TEST.RESULTS"

860 ONERR GOTO 900
870 X = X + 1
880 INPUT TSS(X)
890 GOTO 870
900 POKE 216,0
910 PRINT D$;"CLOSE TEST.RESULTS
    "
920 FOR NUM = 1 TO X - 1
930 PRINT D$;"OPEN "TSS(NUM)
940 PRINT D$;"READ "TSS(NUM)
950 INPUT N1$: INPUT N2$: INPUT
    N3$
960 INPUT NMBR
970 FOR Z = 1 TO NMBR
980 INPUT A1$(Z),A2$(Z),A3$(Z),A
    4$(Z)
990 NEXT Z
1000 PRINT D$;"CLOSE "TSS(NUM)
1010 PRINT D$;"PR#";PR
1020 PRINT SPC( 40 - ( LEN (N1$

```

```

      ) / 2));N1$
1030 PRINT SPC( 40 - ( LEN (N2$
      ) / 2));N2$
1040 PRINT SPC( 40 - ( LEN (N3$
      ) / 2));N3$
1050 PRINT
1060 FOR Z = 1 TO NMBR STEP 5
1070 PRINT A1$(Z);
1080 FOR Q = 2 TO 5
1090 PRINT SPC( 16 - LEN (A1$(
      Q + Z - 2)));A1$(Q + Z - 1);

1100 NEXT Q
1110 PRINT
1120 PRINT A2$(Z);
1130 FOR Q = 2 TO 5
1140 PRINT SPC( 16 - LEN (A2$(
      Q + Z - 2)));A2$(Q + Z - 1);

1150 NEXT Q
1160 PRINT
1170 PRINT A3$(Z);
1180 FOR Q = 2 TO 5
1190 PRINT SPC( 16 - LEN (A3$(
      Q + Z - 2)));A3$(Q + Z - 1);

1200 NEXT Q
1210 PRINT
1220 PRINT A4$(Z);
1230 FOR Q = 2 TO 5
1240 PRINT SPC( 16 - LEN (A4$(
      Q + Z - 2)));A4$(Q + Z - 1);

1250 NEXT Q
1260 PRINT : PRINT
1270 NEXT Z
1280 PRINT : PRINT
1290 FOR Q = 1 TO 79: PRINT "-";
      : NEXT Q
1300 PRINT
1310 PRINT 0$;"PR#0"
1320 NEXT NUM
1330 GOTO 40
1332 REM
      PRINT ONE

1333 HOME : VTAB 12
1334 INPUT "PRINT WHO? ";TSS,1'

1336 ONERR GOTO 1339
1337 NUM = 1:X = 2
1338 GOTO 920

```

```

1339 HOME : VTAB 12: PRINT TSS(1
) " IS NOT ON FILE PLEASE": PRIN
"CHECK SPELLING AND TRY AGAI
N": VTAB 23: INVERSE : PRINT
"PRESS ANY KEY TO CONTINUE":
NORMAL : WAIT - 16384,128:
PUKE - 16368,U: PUKE 216,U
: GOTO 40
1340 REM

```

#### EXIT TO SYSTEM

```

1350 HOME
1360 VTAB 8
1370 PRINT "*****
*****"
1380 PRINT "*"
          "*"
1390 PRINT "*"          PROGR
AM BY          "*"
1400 PRINT "*"          BRIAN S.
PLOTKIN        "*"
1410 PRINT "*"          (C) 04-
10-85          "*"
1420 PRINT "*"
          "*"
1430 PRINT "*****
*****"
1440 NEW
1450 END
1460 REM

```

#### OPEN NEW DATA

```

1470 PRINT D$;"OPEN "TSS",L20"
1480 PRINT D$;"WRITE "TSS",RU"
1490 PRINT U
1500 PRINT D$;"CLOSE "TSS
1510 PUKE 216,U
1520 REC = 0
1530 GOTO 370
1540 HOME : VTAB 12
1550 PRINT
1560 INPUT "CREATE/USE DATA SET
# :";DT
1570 TSS = "TEST.DATA" + STR$ (U
T)
1580 HOME
1590 RETURN

```

# TEST.EDIT

```

10 UNERR GOTO 800
20 D$ = CHR$(13) + CHR$(4)
30 TEXT : HOME
40 VTAB 12
50 PRINT "1) LIST DATA"
60 PRINT "2) EDIT DATA"
70 PRINT "3) RETURN TO MAIN MENU"
  "
80 PRINT : PRINT
90 PRINT "CHOOSE 1-3 :";
100 GET A$
110 PRINT A$
120 A = VAL (A$)
130 IF A < 1 OR A > 3 THEN 30
140 ON A GOTO 150,330,630
150 REM

```

## LIST DATA

```

160 GOSUB 730
170 HOME
180 VTAB 12
190 INPUT "PRINTER SLOT :";PR
200 PRINT D$;"PR#";PR
210 PRINT D$;"OPEN ";TSS$;"L20"
220 PRINT D$;"READ ";TSS$;"R0"
230 INPUT REC
240 FOR A = 1 TO REC
250 PRINT D$;"READ ";TSS$;"R";A
260 INPUT A$
270 PRINT A$. "A$;
280 NEXT A
290 PRINT D$;"PR#0"
300 PRINT D$;"CLOSE ";TSS$
310 GOSUB 660
320 GOTO 30
330 REM

```

## EDIT DATA

```

340 GOSUB 730
350 HOME
360 VTAB 12
370 INPUT "EDIT DATA # :";ED
380 PRINT D$;"OPEN ";TSS$;"L20"
390 PRINT D$;"READ ";TSS$;"R";ED

```

```

400 INPUT AS
410 PRINT D$;"CLOSE ";TSS
420 HOME
430 VTAB 12
440 PRINT "DATA CURRENTLY IS :";
    AS
450 INPUT "CHANGE TO          :";
    BS
460 VTAB 16
470 PRINT "CHANGE ";AS;" TO ";BS
    " ? (Y/N) :";
480 GET QS
490 PRINT
500 IF QS < > "Y" AND QS < > "
    N" THEN 460
510 IF QS < > "Y" THEN 560
520 PRINT D$;"OPEN ";TSS;"L20"
530 PRINT D$;"WRITE ";TSS;"R";E
    U
540 PRINT BS
550 PRINT D$;"CLOSE ";TSS
560 HOME
570 VTAB 12
580 PRINT "EDIT ANOTHER ? ";
590 GET QS
600 IF QS < > "Y" AND QS < > "
    N" THEN 560
610 IF QS = "N" THEN 30
620 GOTO 350
630 REM

```

#### RUN MAIN MENU

```

640 PRINT D$;"RUN TEST.MAIN"
650 REM

```

#### SUBROUTINES

```

660 VTAB 23
670 INVERSE
680 PRINT "PRESS ANY KEY TO CON-
    INUE"
690 WAIT - 16384,128
700 POKE - 16368,0
710 NORMAL
720 RETURN

```

```
730 HOME
740 VTAB 12
750 INPUT "USE DATA SET # :";AS
760 PRINT
770 HOME : VTAB 12
780 TS$ = "TEST.DATA" + AS
790 RETURN
800 REM
```

#### ERROR

```
810 HOME
820 VTAB 12
830 PRINT "YOU MUST FIRST ENTER
      THE DATA!"
840 FOR X = 1 TO 1500: NEXT X
850 POKE 216,0
860 GOTO 630
```

# TEST.MICRO

```

1  HOME : IF PEEK (768) = 76 THEN
    CALL 777
2  IF PEEK (768) = 76 THEN GOTO
    4
3  D$ = CHR$ (4): PRINT D$"BLUAD
    B.MILLISECONDS"
4  CALL 768: REM SET UP INTERRUPT
    TS
5  B = 256: HOME : REM QUESTIONAB
    LE USE OF VAR B
6  HOME
20 TEXT : HOME :SLOT = 2
30 PK = - 16384
40 D$ = CHR$ (4):RD = PK:CL = RD
    + 16
50 DIM A$(25),INCR$(25)
70 INPUT "USE DATA SET # :";DT
80 TS$ = "TEST.DATA" + STR$ (DT)

90 HOME : VTAB 12
100 INPUT "SUBJECT NAME :";N1$
110 INPUT "TESTING DATE :";N2$
120 INPUT "TEST METHOD :";N3$
130 PRINT D$;"OPEN "TS$","L20"
140 PRINT D$;"READ "TS$","RU"
150 INPUT REC
160 IF REC = 0 THEN 690
170 FOR X = 1 TO REC
180 PRINT D$;"READ "TS$","R"X
190 INPUT A$(X)
200 NEXT X
210 PRINT D$;"CLOSE "TS$
220 X = 1
230 PRINT CHR$ (4);"IN#2"
240 HOME : VTAB 3: PRINT SPC( 1
    5);"ENTER DATA"
250 VTAB 4: PRINT SPC( 15);"NUM
    BER :";X
260 PRINT : PRINT SPC( 15);"ENT
    ER :";
270 GET TS
300 IF ASC (TS) < 97 THEN 320
310 TS = CHR$ ( ASC (TS) - 32)
320 PRINT TS;
325 CALL 771: REM RESET COUNT A
    ND STARTS TIMER
330 Q$ = Q$ + TS
350 GET TS
380 IF ASC (TS) < 97 THEN 400
390 TS = CHR$ ( ASC (TS) - 32)
400 Q$ = Q$ + TS
410 PRINT TS;

```

```

420 IF LEN (Q$) < LEN (A$(X)) THE
350
430 PRINT
431 CALL 774: REM STOP TIMER
432 MS = 0: FOR A = 780 TO 783:MS
    = MS * B + PEEK (A): NEXT
433 C = MS / 1024:S = INT (C):MS
    = (C - S) * 1000
440 FOR Q = 1 TO LEN (A$(X))
450 IF MID$ (Q$,Q,1) < > MID$
    (A$(X),Q,1) THEN WR = WR + 1
460 NEXT Q
461 TIME = S + (MS / 1000)
462 TIME = TIME * 1000
463 TIME = INT (TIME):TIME = TIM
    E / 1000
480 INCR$(X) = STR$ (WR) + CHR$
    (13) + Q$ + CHR$ (13) + A$(
    X) + CHR$ (13) + STR$ (TIM
    E) + " sec"
490 X = X + 1
500 Q$ = "":TIME = 0:WR = 0
510 IF X < = REC THEN 240
511 SLOT = 4
530 TT$ = "TEST.RESULTS"
540 PRINT D$;"APPEND "TT$
550 PRINT D$;"WRITE "TT$
560 PRINT N1$
570 PRINT D$;"CLOSE "TT$
580 PRINT D$;"OPEN "N1$
590 PRINT D$;"WRITE "N1$
600 PRINT N1$: PRINT N2$: PRINT
    N3$: PRINT REC
610 FOR X = 1 TO 25
620 PRINT INCR$(X)
630 NEXT X
640 PRINT D$;"CLOSE "N1$
650 GOTO 720
660 PRINT D$;"OPEN "TT$
670 PUKE 216,0
680 GOTO 550
690 HOME : VTAB 12
700 PRINT "YOU MUST HAVE FIRST E
    NTERED THE DATA TO BE TES
    TED!!"
710 FOR X = 1 TO 1000: NEXT X
720 PRINT D$;"IN#0"
730 PRINT D$;"RUN TEST.MAIN"

```

TEST.PRACTICE

```
10 TEXT : HOME
20 PRINT "PRESS CTRL-OPEN APPLE-
  RESET TO EXIT"
30 PUK 34,1
40 SLOT = 2
50 ONERR GOTO 120
60 PRINT CHR$ (4);"IN#";SLOT
70 GET A$
80 IF A$ = CHR$ (3) THEN 120
90 IF A$ = CHR$ (8) THEN PRINT
  CHR$ (8);" ";
100 PRINT A$;
110 GOTO 70
120 PRINT CHR$ (4);"IN#U"
130 PRINT CHR$ (4);"PR#U"
140 PUK 216,0
150 TEXT
160 PRINT CHR$ (4);"RUN TEST.MA
  IN"
```

# TEST KEYBOARD

```

1  HOME : IF PEEK (768) = 76 THEN
      CALL 777
2  IF PEEK (768) = 76 THEN GOTO
      4
3  D$ = CHR$ (4): PRINT D$"BLUAD
      B.MILLISECONDS"
4  CALL 768: REM SET UP INTERRUPT
      TS
5  B = 256
6  HOME
20 D$ = CHR$ (4):RD = - 16384:C
      L = - 16368
30 DIM A$(25),INCR$(25)
40 HOME : VTAB 12
50 INPUT "USE DATA SET # :";DT
60 TS$ = "TEST.DATA" + STR$ (DT)

70 ONERR GOTO 720
80 GOSUB 760
90 HOME
100 VTAB 12
110 INPUT "SUBJECT NAME :";N1$
120 INPUT "TESTING DATE :";N2$
130 INPUT "TEST METHOD :";N3$
140 PRINT D$;"OPEN "TS$",L20"
150 PRINT D$;"READ "TS$",R0"
160 INPUT REC
170 IF REC = 0 THEN 720
180 FOR X = 1 TO 25
190 PRINT D$;"READ "TS$",R"X
200 INPUT A$(X)
210 NEXT X
220 PRINT D$;"CLOSE "TS$
230 X = 1
240 HOME : VTAB 3: PRINT SPC( 1
      5);"ENTER DATA"
250 VTAB 4: PRINT SPC( 15);"NUM
      BER :";X
260 IF PEEK (RD) < 127 THEN 260

270 Q1$ = CHR$ ( PEEK (RD) - 128
      )
280 IF Q1$ = CHR$ (13) THEN 450

290 POKE CL,0
300 CALL 771: REM START COUNTER
310 IF PEEK (RD) < 127 THEN 310

```

```

320 Q = VAL (Q1$):Q1$ = CHR$ ( PEEK
      (RD) - 123): POKE CL,U
330 GOSUB 880
340 VTAB 12: HTAB 12: PRINT Q$
350 IF PEEK (RD) < 127 THEN 350

360 Q1$ = CHR$ ( PEEK (RD) - 128
      ): POKE CL,U
370 IF Q1$ = CHR$ (13) THEN 450

380 IF PEEK (RD) < 127 THEN 380

390 Q = VAL (Q1$):Q1$ = CHR$ ( PEEK
      (RD) - 128): POKE CL,U
400 GOSUB 880
410 VTAB 12: HTAB 12: PRINT Q$
420 IF LEN (Q$) = LEN (A$(X)) THEN
      450
440 GOTO 350
450 POKE CL,U
455 CALL 774: REM STOP TIMER
460 MS = 0: FOR A = 780 TO 783:MS
      = MS * B + PEEK (A): NEXT

461 C = MS / 1024:S = INT (C):MS
      = (C - S) * 1000
462 TIME = S + (MS / 1000)
463 TIME = TIME * 1000
464 TIME = INT (TIME):TIME = TIM
      E / 1000
470 FOR Z = 1 TO LEN (A$(X))
480 IF MID$ (A$(X),Z,1) < > MID$
      (Q$,Z,1) THEN WR = WR + 1
490 NEXT Z
500 INCR$(X) = STR$ (WR) + CHR$
      (13) + Q$ + CHR$ (13) + A$(
      X) + CHR$ (13) + STR$ (TIM
      E) + " sec"
510 WR = 0:TIME = 0:Q$ = ""
520 X = X + 1
530 IF X > REC THEN 550
540 GOTO 240
550 ONERR GOTO 690
560 TT$ = "TEST.RESULTS"
570 PRINT D$;"APPEND "TT$
580 PRINT D$;"WRITE "TT$
590 PRINT N1$
600 PRINT D$;"CLOSE "TT$
610 PRINT D$;"OPEN ";N1$
620 PRINT D$;"WRITE ";N1$
630 PRINT N1$: PRINT N2$: PRINT
      N3$: PRINT REC

```

```

640 FOR X = 1 TO 25
650 PRINT INPAD
660 NEXT X
670 PRINT DS;"CLOSE ";NIS
680 GOTO 750
690 PRINT DS;"OPEN "TTS
700 PUKE 216,0
710 GOTO 580
720 HOME : VTAB 12
730 PRINT "YOU MUST HAVE FIRST E
      NTERED THE DATA      TO BE TES
      TED!!"
740 FOR X = 1 TO 1000: NEXT X
750 PRINT DS;"RUN TEST.MAIN"
760 REM

```

#### DATA VARIABLES

```

770 Z$(1) = "STU"
780 Z$(2) = "VWX"
790 Z$(3) = "Y Z"
800 Z$(4) = "JKL"
810 Z$(5) = "MNU"
820 Z$(6) = "PQR"
830 Z$(7) = "ABC"
840 Z$(8) = "DEF"
850 Z$(9) = "GHI"
860 RETURN
870 REM

```

#### SUB-SPLITTING

```

880 IF Q1$ = "U" THEN Q$ = Q$ +
      LEFT$(Z$(Q),1)
890 IF Q1$ = "," THEN Q$ = Q$ +
      MID$(Z$(Q),2,1)
900 IF Q1$ = "." THEN Q$ = Q$ +
      RIGHT$(Z$(Q),1)
910 RETURN

```

APPENDIX C  
INFORMED CONSENT FORM

INSTRUMENT TO OBTAIN INFORMED CONSENT

I, \_\_\_\_\_, have been informed by Mr. Sheldon A. Wolstein that I have been selected to participate in a study concerning the learning and use of a new single-handed keyboard and the use of a 4x4 numeric keypad.

1. I have been given an explanation of the procedures to be followed, including an identification of those which are experimental.
2. I have been given a description of the attendant discomforts and risks, which include keying in data on both types of keyboards which is presented by a cassette tape player.
3. I have been given a description of the benefits to be expected.
4. I have been given a description of appropriate alternative procedures that would be advantageous to me.
5. I have been offered an answer to any inquiries concerning the procedures.
6. I have been instructed that I am free to withdraw my consent and to discontinue my participation in the project or activity at any time.
7. I have been assured that steps will be taken to ensure confidentiality of the results.
8. I understand that in the event of physical injury resulting from the research procedures described to me that there will be no financial compensation or free medical treatment offered to me.
9. I have not been requested to waive or release the institution, its agents or sponsors from liability for the negligence of its agents or employees.

I, the undersigned, have understood the above explanations and give my consent to my voluntary participation in Mr. Sheldon Wolstein's research project.

\_\_\_\_\_  
Signature of subject

Date: \_\_\_\_\_

Location: \_\_\_\_\_

Principal Investigator:

Sheldon A. Wolstein  
1211 University Oaks, D.S., TX  
(409) 696-7510

Another Contact Person:

Dr. Rodger Koppa  
Texas Transportation Institute  
Human Factors Division, D.S., TX  
(409) 845-2511

APPENDIX D  
TRAINING MATERIAL FOR MNEMONIC CONDITION

Thank you again for agreeing to participate in this study.

The purpose of this part of the study is to teach you how to use the Microwriter keyboard.

If you have any questions please don't hesitate to ask.

#### ABOUT THE MICROWRITER

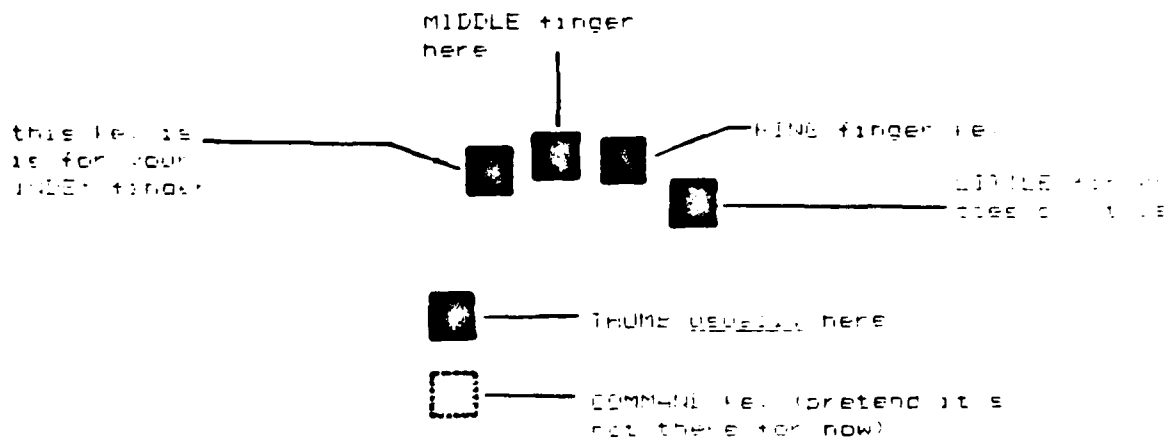
The Microwriter is a relatively new device, developed by an American film director living in England, Cy Enfield. The company marketing the device is called Microwriter LTD., and is wholly owned by Standard Life Assurance Co. which is a large insurance firm from England.

Microwriter is known as a single hand, six key, handprint, chord keyboard. That it is single hand operation on six keys is obvious. "Handprint" means that the keys are laid out so the hand rests naturally on the keys as opposed to having the keys in a 2 X 3 matrix. "Chord" refers to the fact that generally more than one key must be struck to produce a character, similar to piano chords.

#### THINGS YOU NEED TO KNOW FIRST

It is not like a conventional keyboard. There are only 5 keys on the **MAIN KEYBOARD** plus the "COMMAND KEY" (which we won't need for a while so try to ignore it).

Here is a picture of the keyboard, showing where each finger of your right hand is supposed to go.



Now there is a very important point:

**DON'T** wave your fingers about on the keys or use them on any key other than the one they're supposed to use (as shown on the chart above).

This one-finger-to-one-key correspondence will make the microwriter easier to use. Microwriting is using one or more keys together at the same time to produce one letter, number, punctuation mark, etc. The important thing to remember at this stage is that using the wrong finger on a wrong key will slow down your learning and lead to lots of mistakes.

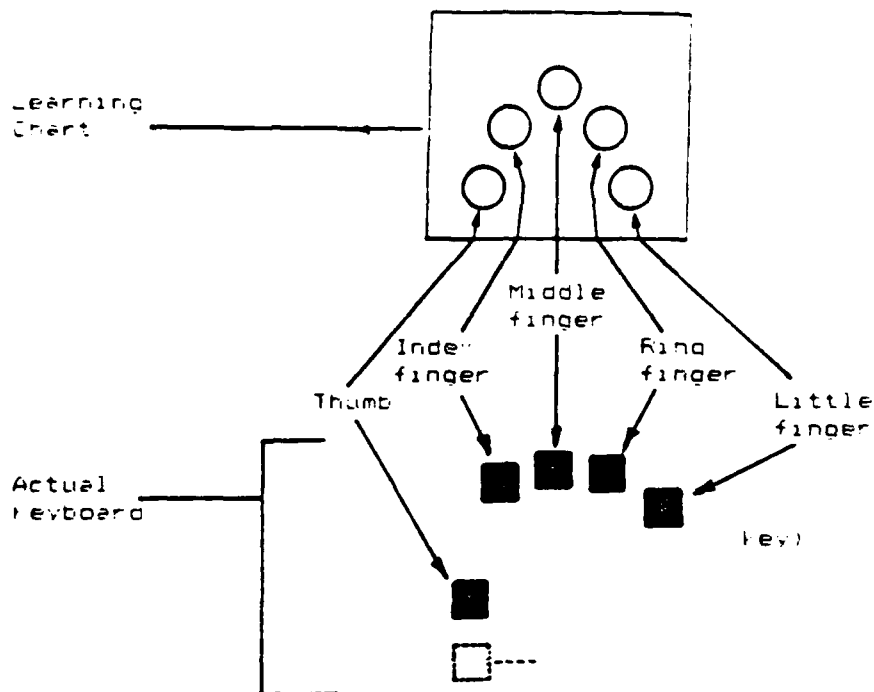
Also, once you start, you'll notice a couple of things about the keys themselves which make them different from the conventional typewriter. First, the keys are touch-sensitive, much lighter than on a typewriter. This helps you to get very fast, but does mean that you'll make mistakes to begin with. Second, the letters you type are not created when the keys are pressed but instead they are generated when the keys are released. This means that you don't have to get all the keys down at the same instant, just so long as all of the necessary keys get pressed.

Take a little time now, with the machine off, to get acquainted with it and to get used to the feel of the keys and the positions of the fingers. Get into the habit now of keeping each finger on its own key and your thumb normally on the UPPER of the 2 thumb keys.

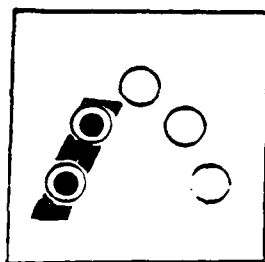
One note about the lower thumb key, the COMMAND key. If you press it by accident, different characters will be produced. If you notice that the incorrect characters are being produced by the correct chord, just press both thumb keys together to clear it.

## HOW TO FORM THE LETTERS

It will all be based on this chart:



This chart will show which keys are to be depressed for each character. For example, the letter "l"



The darkened circles correspond to the keys which must be pushed for that letter.

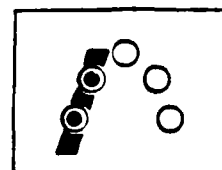
Please do not turn the page

If you have any questions so far, please ask them now. If not, inform Sheldon that you are ready to begin.

You will notice that in the example "I", the keys pressed can be related to the shape of the handwritten letter.

This is how you handwrite the letter "I"

You Microwrite the letter "I" like this, creating the shapes with your finger tips.

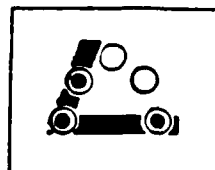


This is a memory aid to help you learn the alphabet. All the letters will have this.

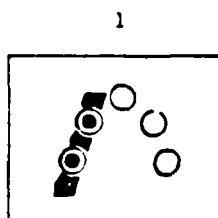
The "L" works the same way:

This is how you handwrite the letter "L"

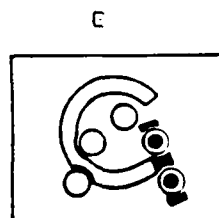
You Microwrite the letter "L" like this



You will find that a lot of the letters form natural pairs of opposites based on the SHAPES, which can be thought of as "mirror images". Try to remember the letters as these pairs: it's easier. For instance, the opposites of the two you've done so far are "G" and "J":

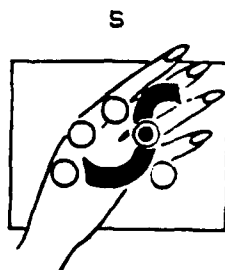


opposites

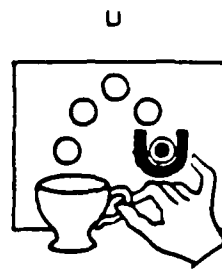


the downstroke of the "G"

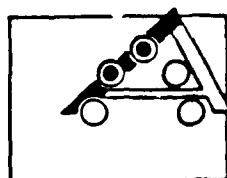




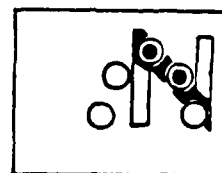
Signet ring finger for "S"  
A



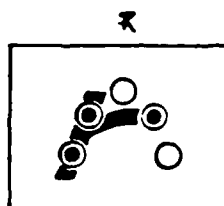
Little finger: very "U"  
N



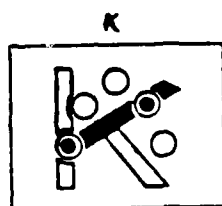
Line to Apex of "A"



down line of "N"



shape of small "R"



Upstroke of the "K"

Made any mistakes yet? Don't worry, just continue on, but remember accuracy first, speed later.

You've just covered half of the alphabet. Here's the rest:

AD-A185 420

AN EXPERIMENTAL STUDY OF A SIX KEY HANDPRINT CHORD  
KEYBOARD(U) TEXAS TRANSPORTATION INST COLLEGE STATION  
S A MMLSTEIN MAY 86 RF-7053-21 DAAA15-86-K-0018

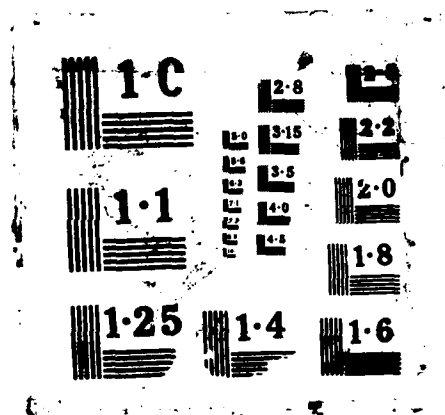
2/2

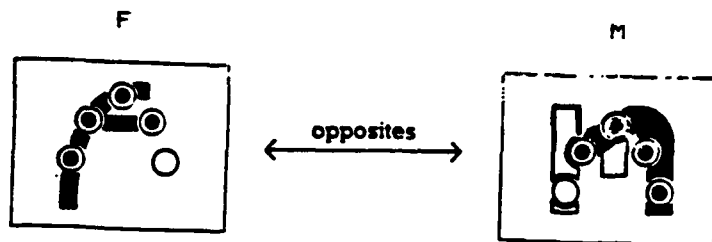
UNCLASSIFIED

F/G 12/6

NL

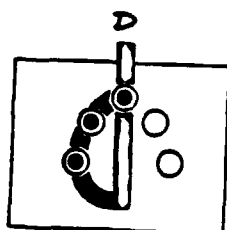




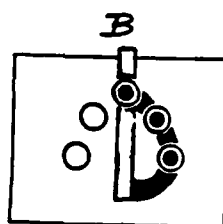


First Four Fingers For "F"

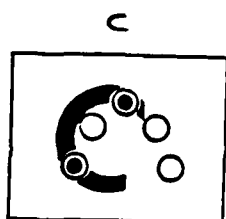
Most fingers Make "M"



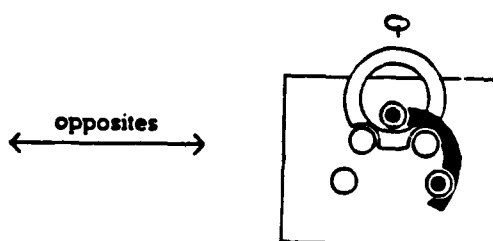
Dome of the "D"



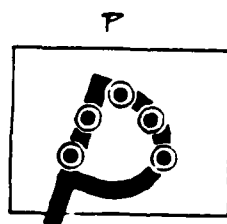
Back of the "B"



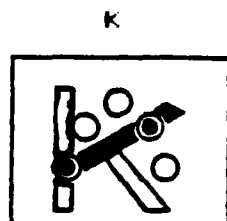
Curl round for "C"



Make the tail from the centre, Q

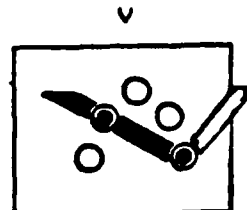


complete Press for "P"

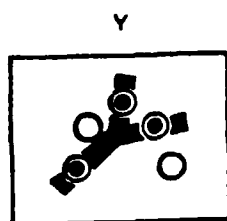


the upstroke of the "K"

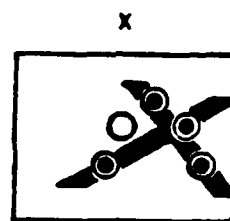
← opposites →



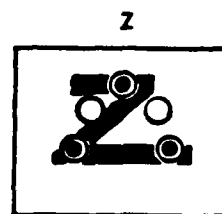
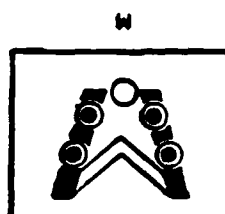
downstroke of the "V"



looks like a "Y"



All Xcept your index



The two sides of the "W"      Zig Zag between the keys  
Now if you want to practice some writing, try an old standard:

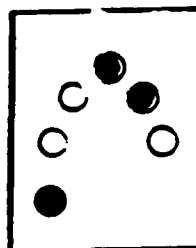
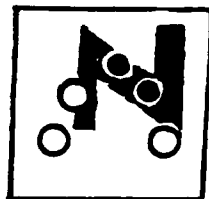
THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG

Don't forget to use the cue card if necessary.

Now try:

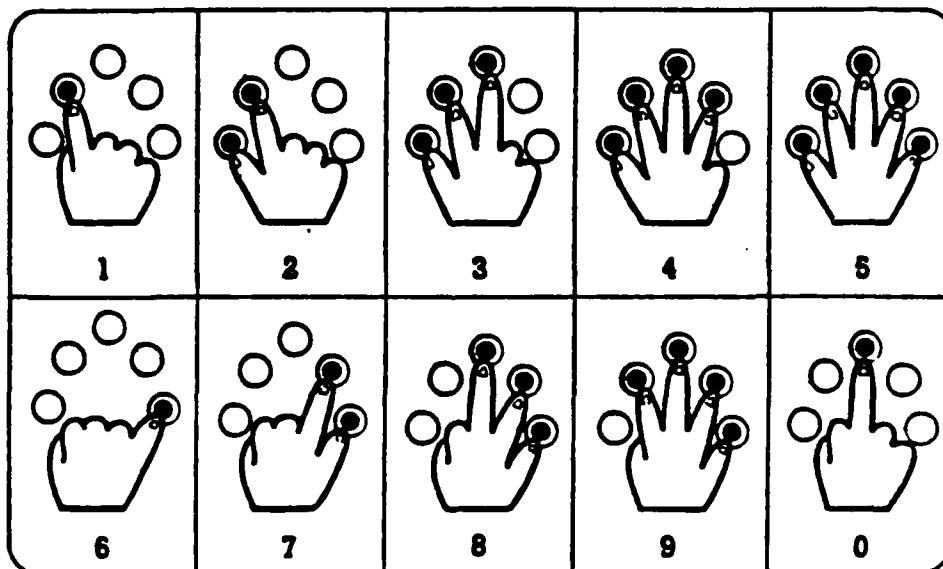
THE ZEAL OF THE ARCHITECT WAS BEING EXERCISED CONTINUALLY IN  
CONJUNCTION WITH A KEEN QUANTITY SURVEYOR IN THE DESIGN OF QUANT BUT  
PRETTY MAISONNETTES.

Now you're ready for numbers. If you recall, we mentioned only briefly the command key and how to clear it. Now we have to use it to get to the numbers. To change to the mode which has the numbers you press the command key and the chord for the letter "N" (for "N"umber).



Pressing the command "N" once will make the next regular letter you type a number, then the Microwriter will automatically shift back into the alphabet mode. If you have more than one number in a row to type you should lock into the number mode by pressing the command "N" twice. Type the line of numbers and when you have another letter to type, shift back to the alphabet mode by pressing both thumb keys at the same time.

Here are the numbers. Go ahead and lock the machine into the number mode and practice some.



That's all you have to learn. Now for the practice sessions to gain speed. Remember at first you should concentrate on accuracy, with speed secondary. After a while you should be able to increase your speed without increasing errors.

APPENDIX E  
TRAINING MATERIAL FOR PLAIN CONDITION

Thank you again for agreeing to participate in this study.

The purpose of this part of the study is to teach you how to use the Microwriter keyboard.

If you have any questions please don't hesitate to ask.

#### ABOUT THE MICROWRITER

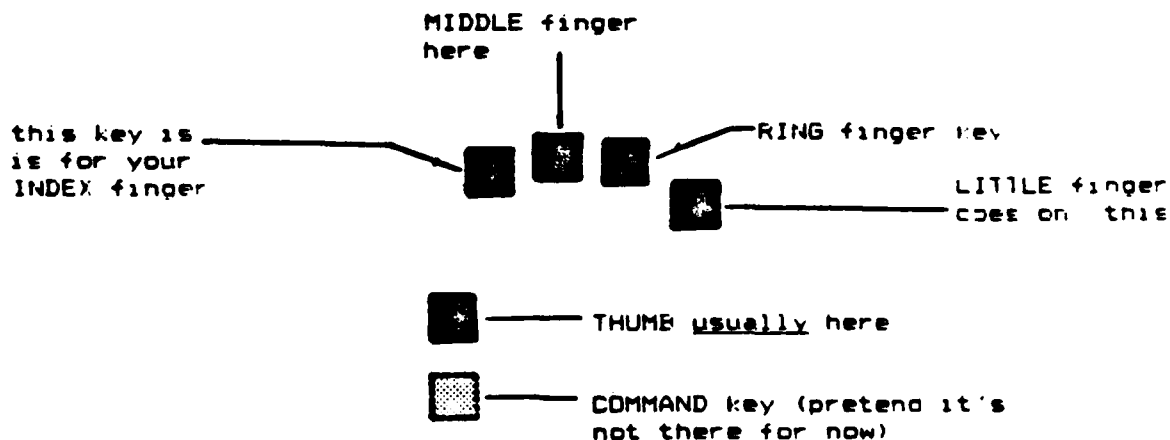
The Microwriter is a relatively new device, developed by an American film director living in England, Cy Enfield. The company marketing the device is called Microwriter LTD., and is wholly owned by Hambro Life Assurance Co. which is a large insurance firm from England.

Microwriter is known as a single hand, six key, handprint chord keyboard. That it is single hand operation on six keys is obvious. "Handprint" means that the keys are laid out so the hand rests naturally on the keys as opposed to having the keys in a 2 X 3 matrix. "Chord" refers to the fact that generally more than one key must be struck to produce a character, similar to piano chords.

#### THINGS YOU NEED TO KNOW FIRST

It's not like a conventional keyboard. There are only 5 keys on the MAIN KEYBOARD plus the "COMMAND KEY" (which we won't need for a while so try to ignore it)

Here is a picture of the keyboard, showing where each finger on your right hand is supposed to go.



Now there is a very important rule:

DON'T wave your fingers about on the keys or use them on any key other than the one they're supposed to use (as shown on the chart above).

This one-finger-to-one-key correspondence is what makes the Microwriter so easy to use. Microwriting is using one OR MORE keys together at the same time to produce one letter, number, punctuation mark, etc. The important thing to remember at this stage is that using the wrong finger on the wrong key will slow down your learning and lead to lots of mistakes.

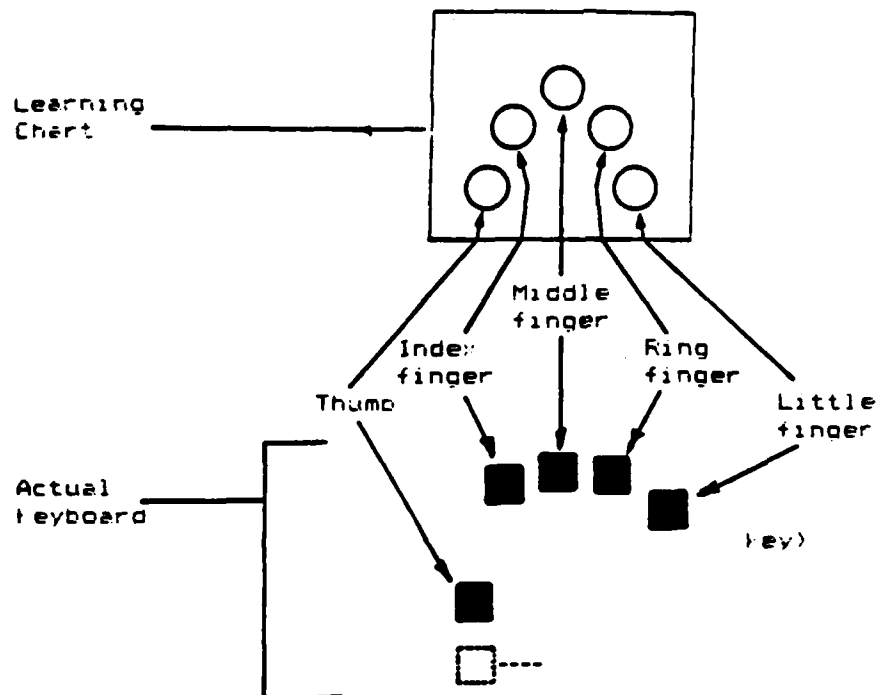
Also, once you start, you'll notice a couple of things about the keys themselves which make them different from the conventional typewriter. First, the keys are very touch-sensitive, much lighter than on a typewriter. This helps you to get very fast, but does mean that you'll make mistakes to begin with. Second, the letters you type are not created when the keys are pressed but instead they are generated when the keys are released. This means that you don't have to get all the keys down at the same instant, just so long as all of the necessary keys get pressed.

Take a little time now, with the machine off, to get acquainted with it and to get used to the feel of the keys and the positions of the fingers. Get into the habit now of keeping each finger on its own key and your thumb normally on the UPPER of the 2 thumb keys.

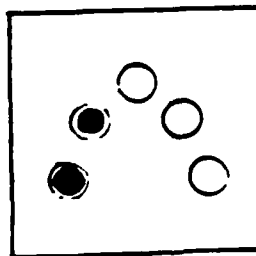
One note about the lower thumb key, the COMMAND key. If you press it by accident, different characters will be produced. If you notice that the incorrect characters are being produced by the correct chord, just press both thumb keys together to clear it.

## HOW TO FORM THE LETTERS

It will all be based on this chart:



This chart will show which keys are to be depressed for each character. For example, the letter "l"

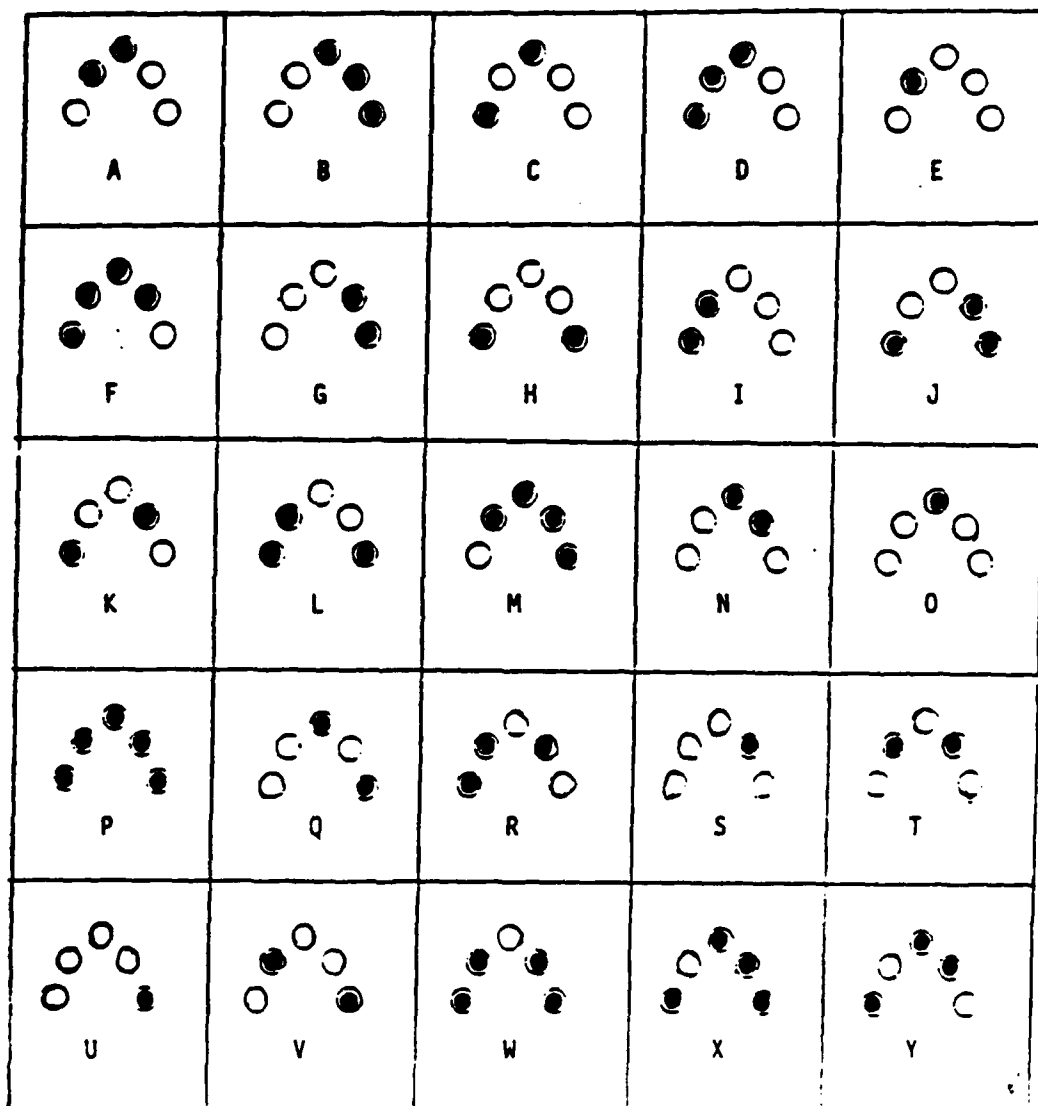


The denoted circles correspond to the keys which must be pushed for that letter.

Please do not turn the page

If you have any questions so far, please ask them now. If not, inform Sheldon that you are ready to begin.

These are the letter chords. Please feel free to practice as you go along.



Now if you want to practice some writing, try an old standard:

THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG

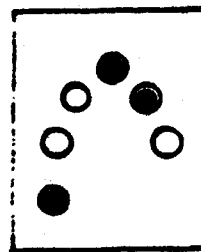
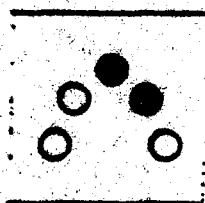
Don't forget to use the cue card if necessary.

Now to

THE ZEPHYRUS THE ARCHITECT WAS BEING EMPLOYED CONTINUALLY IN CONNECTION WITH A RESEARCH SURVEY IN THE DESIGN OF QUANTUM BOSS-ROCKETRY SYSTEMS.

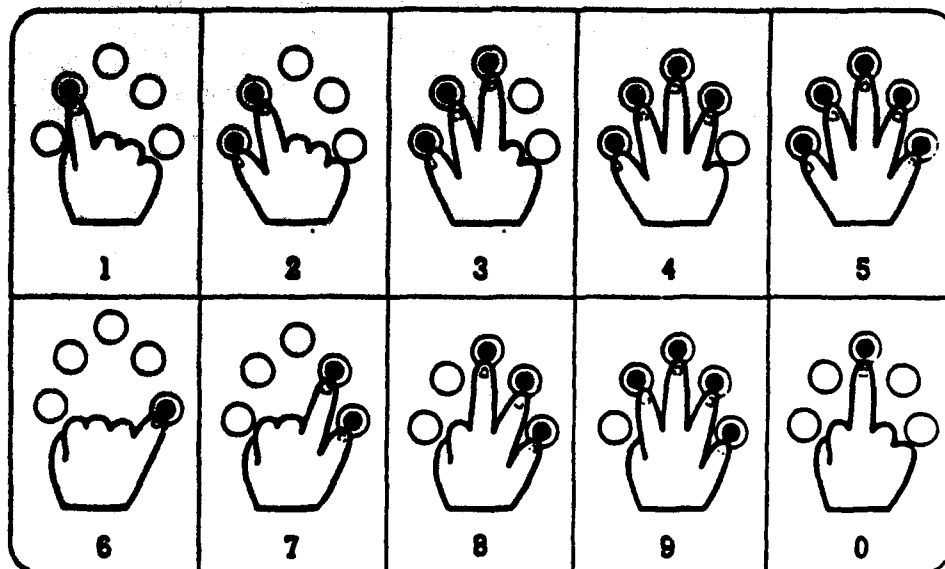


Are you ready for numbers. If you recall, we mentioned only briefly the command key and how to clear it. Now we have to use it to get to the numbers. To change to the mode which has the numbers you press the command key and the chord for the letter "N" (for "N"umber).



Pressing the command "N" once will make the next regular letter you type a number, then the Microwriter will automatically shift back into the alphabet mode. If you have more than one number in a row to type you should lock into the number mode by pressing the command "N" twice. Type the line of numbers and when you have another letter to type, shift back to the alphabet mode by pressing both thumb keys at the same time.

Here are the numbers. Go ahead and lock the machine into the number mode and practice some.



That's all you have to learn. Now for the practice sessions to gain speed. Remember at first you should concentrate on accuracy, with speed secondary. After a while you should be able to increase your speed without increasing errors.

## APPENDIX F

### TRAINING MATERIAL FOR KEYPAD CONDITION

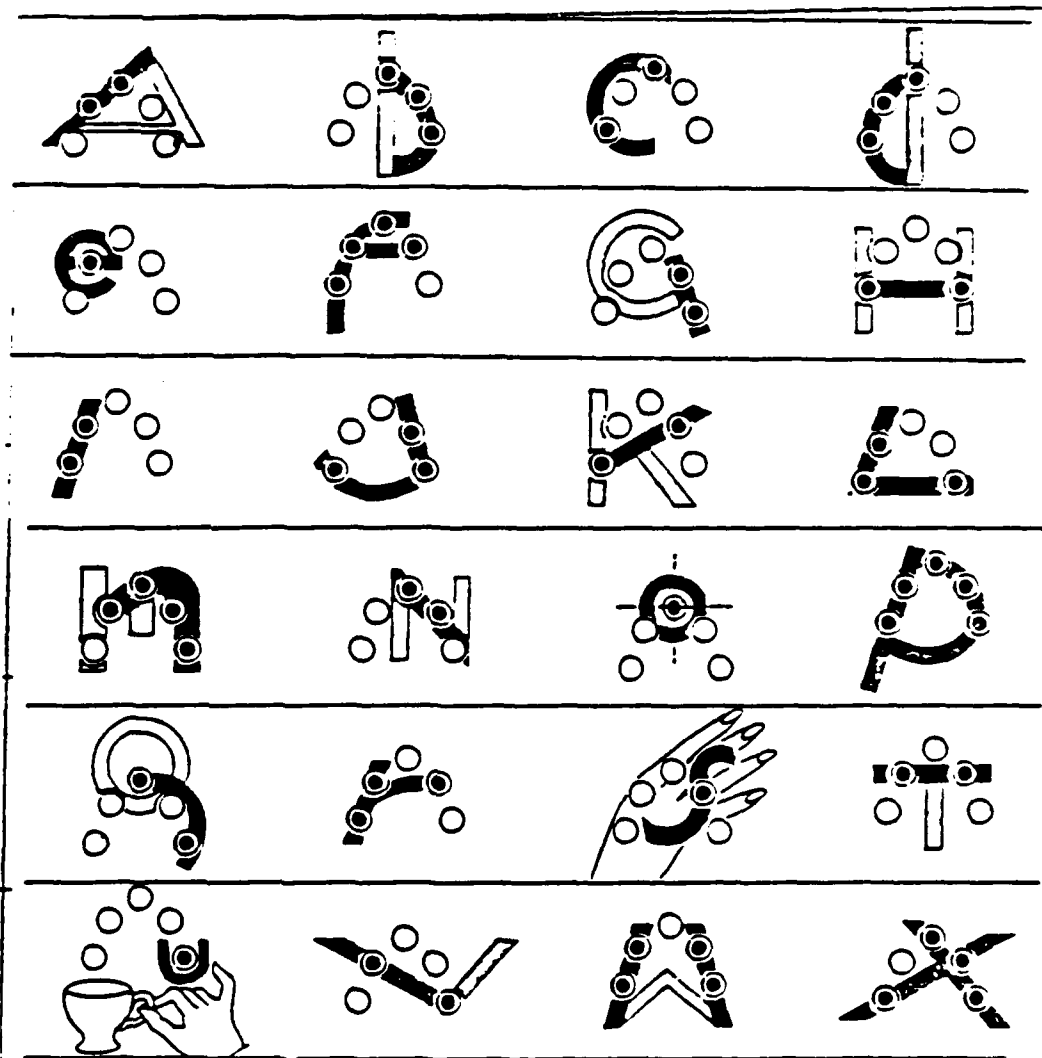
Thank you again for agreeing to participate in this study. The keypad you will be using is a standard 4x4 numeric keypad with a few buttons changed. As you can see, on either side of the "0" there are two arrow buttons. These are to be used in entering the alphabet.

When you need to enter a letter, locate it on one of the regular number keys. Press the key with the desired letter and then press either of the arrows or the "0" to show which of the letters is chosen. For instance the letter "M" would be chosen by pressing the "5" key and then the left pointing arrow "←".

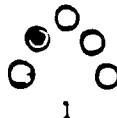


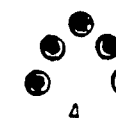
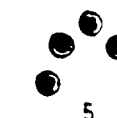
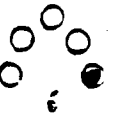

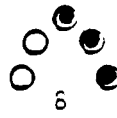

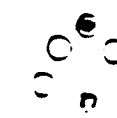
That's all there is to it. First there will be a timed run to see how well you can do without any practice, then some practice tests and at the end of the hour another timed run. Ask any questions now. If you have no questions, please let Sheldon know you're ready.

APPENDIX G  
ONE SHEET CUE CARDS FOR MICROWRITER

# Mnemonic Condition

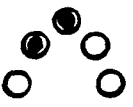
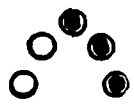
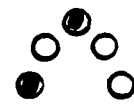

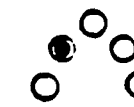

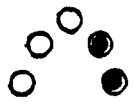
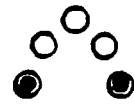
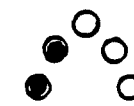
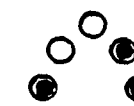
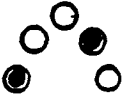
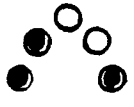
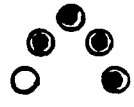
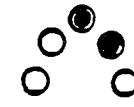
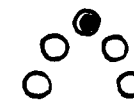
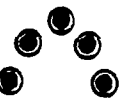
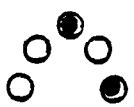
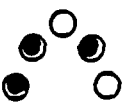
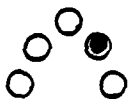
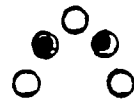
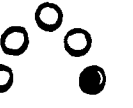
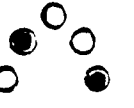
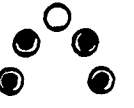

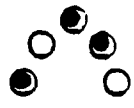


## NUMBERS

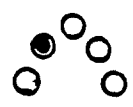
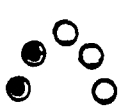
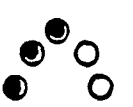
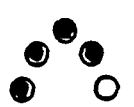
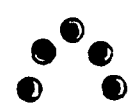
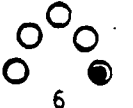

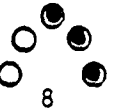

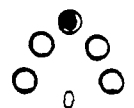
				
				

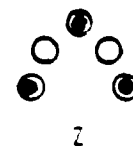
# Plain Condition

These are the letter chords. Please feel free to practice as you go along.

 A	 B	 C	 D	 E
 F	 G	 H	 I	 J
 K	 L	 M	 N	 O
 P	 Q	 R	 S	 T
 U	 V	 W	 X	 Y

## NUMBERS

 1	 2	 3	 4	 5
 6	 7	 8	 9	 0



## APPENDIX H

### EXAMPLE OF PRACTICE ARTICLE

Barrons reports that earlier this year major financial institutions invested large amounts in airlines. Leading the air lines in the top 50 net purchases lists was Delta Air Lines, with 321.6 million of shares purchased, 202.7 million sold with 117.9 million as the net transaction from a holding of 1218.0

For the picture of the high tech companies refer to the chart below, all amounts in millions of dollars:

STOCK	PURCHASES	SALES	HOLDINGS
McDon Doug.	288.8	110.8	1188.4
Matsush. Elec.	167.5	17.9	379.5
Viacom	181.2	57.9	420.4
Xerox	286.9	164.5	2435.7
Tandv	272.5	151.8	1077.7
Martin Marietta	229.1	121.5	1059.7
ITT	355.5	250.8	1721.0
E Systems	172.0	71.4	380.7
Boeing	504.6	406.1	3610.7

For other companies' stock, activity was also brisk. Disney shares of 297.6 were bought, 118.4 were sold, and a holding of 887.5 was reported. For McDonalds bought were 350.6, sold were 252.3, and a holding of 3335.2. Reporting institutions also sold 20.6, bought 126.2, and held 311.4 of Dillards Stores stock.

On the down side where these institutions sold off more than they purchased of a particular company's stock were such blue chips as Phillips Petroleum with 920.5 million, Eastman Kodak with 558.1 and 141.6 of Atlantic Richfield. Also dumped were 234.6 million of IBM, 153.7 of Ford, and 66.4 of Coca-Cola.

Overall, the biggest groups bought up were electric power with 1340.8 million in net purchases, drugs with 835.8, air transport with 686.7, and 677.4 worth of entertainment companies. The biggest sales were in hotels and motels with 386.1 million in net sales, foods with 352.3, 288.1 in natural gas pipe and 268.4 in radio-tv broadcasting. Computers, business machines, semiconductors, and electronic equipment which are facing the same slowdown in their shared market when combined accounted for 414.5 million in net sales.

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